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UNDERSTANDING PLUS

By D. B. PRENTICE

Vice-President of the Society

In the "Republic" Plato discussed the plan for education in his ideal state. The acquiring of knowledge, he asserted, is a process which involves four successive phases and these occur at increasing degrees or levels of intellectual effort. They correspond to the mental growth of the individual, a growth which in numerous instances terminates short of the fourth level.

Plato designates these steps in the ladder of learning as perception, faith, understanding and reason. Perhaps it is inaccurate to refer to them as steps for they overlap. The child has faith or conviction in certain matters before it perceives others. For comprehensive knowledge of a single item, however, the steps must be taken in Plato's order and maturity of intellect is a *sine qua non* for the fourth step. Unfortunately possession of such an intellect does not compel ascent.

From his perambulator the child of a few years perceives a motor car. Later, as he daily rides to school with father, his mental conception of this device rises to the level of faith or conviction. He expects that it will perform today as yesterday. He is confident that a turn of the ignition key and depression of the starter switch will produce a running motor, that a clockwise movement of the steering wheel will guide the car around the corner to the right. He does not know why result follows cause, but he is willing to bet it will. Many motorists never bother to leave the second step in the process of acquiring knowledge about their cars.

However, through mechanical inquisitiveness or a required course in physics, our young man learns to understand the behavior of his automobile. He studies combustion, cycles, torque, linkages, gear trains. Every movement, even every sound, can be explained. He "knows his car" and becomes one of that exclusive group, perhaps one per cent of drivers, who can really speak with authority.

This third step, understanding, is achieved by comparatively few because it requires mental exertion and the reward is chiefly personal satisfaction. Our hero may handle his car with greater precision and take it less often to the repair shop, but these achievements do not necessarily gain him recognition from those still on the second step. In fact, if he calls attention to his understanding

even by intelligent and pertinent conversation, he may be rated a bore.

To complete the Platonic climb the fourth step of reasoning must be taken. Continuing our motor car illustration we may list a few items connected with this modern vehicle which even a perfect technical understanding does not include. Item one, the accident record attributable to motor traffic; item two, the effect on central real estate values of suburban housing development made feasible by this form of transportation; item three, the effect on railroad earnings; item four, recent highway improvement; item five, this sources of taxes, its use and abuse; item six, the effect of motoring on health; item seven, relation to the back-to-the-farm movement; item eight, moral effects; item nine, concentration of general business in larger centers; item ten, consolidated schools; etc., etc. It is evident that the part of the motorcar in any of these relationships is of tremendous importance in modern society. These items present problems of vastly more concern than, say, the technical choice between six or eight cylinders, problems which require for their solutions reasoning far beyond understanding.

Of necessity most high school teaching and learning must be at the level of understanding and, even in college, this third step in the process of acquiring knowledge is of prime importance. One mark of differentiation which we expect to find as a product of college training, however, is the ability to use knowledge, to understand the significance of facts. This ability can be developed by the instructor only if he repeatedly carries his students beyond the level of understanding and forces them to exercise their brains at the level of reasoning.

All of us have known great teachers. An analysis of the factors which made them great will, I am certain, reveal that reasoning on the significance of what they taught was quite as important in their classrooms as an understanding of the facts.

PRE-ENGINEERING COLLEGE EDUCATION *

By D. B. STEINMAN

Consulting Engineer, New York City

This opportunity to discuss the relation of general college education to professional training, and to make a plea for a broader and more adequate educational foundation for engineering training, before an audience representing the highest educational leadership of this State, is most welcome.

Practically all who have studied the subject are agreed that there are now three things basically wrong with engineering education. These are:

1. Insufficient educational preparation of entering students for full benefit of an intensive professional education.

2. A too crowded curriculum for four years of study, particularly if the curriculum has to make up for deficiencies of high school preparation besides covering any cultural, economics, or English courses.

3. Inclusion of insufficient education in the humanities for the proper equipment of a professional man.

All of these three shortcomings can be relieved by a single solution, namely, the encouragement of two years of pre-professional study in a college of liberal arts and sciences before enrollment in the engineering schools.

In 1905, the medical profession, under the leadership of its most distinguished educators, reached the same conclusion and embarked on a program of raising the level of medical education. They considered this so important, to the public and to the profession, that the American Medical Association has expended over one million dollars on the accomplishment of this one objective.

Every medical school in the country now requires two to four years of college work before enrollment in the medical school, and 43 states have written this requirement into the licensing law. Now 77 per cent of all medical students are *college graduates* before they enter medical school.

The leading law schools require applicants to have a *college degree* before enrollment, and 29 states by law require two years of pre-legal college study.

* Presented at the Annual Meeting of the Association of Colleges and Universities of the State of New York, at Lake Mohonk, N. Y., October 6, 1939.

I am not here discussing any proposal to *require* two years of pre-engineering college study, but merely a proposal to *encourage* it. This distinction is important in order to avoid a confusion of issues. How can this desired improvement in professional preparation be encouraged?

In the medical profession, it was the educators who had the vision and who led in the progress toward higher standards and standing. Will the engineering educators show equal qualities of self-sacrifice, vision and leadership in genuine coöperation with the aspirations of the engineering profession toward higher standards and standing, or will they resist and retard that progress?

This is an appeal to engineering educators to give sympathetic and open-minded consideration to a proposal toward raising the level of engineering education. I make my plea to the engineering educators to divest themselves of any pre-conceived prejudice or crystallized opinion on the subject and to place the future of the profession and the higher ideals of professional education above self-interest or the immediate competitive interests of their individual schools. Here is a wonderful opportunity for engineering educators who have the sincerity, vision and courage to assume the leadership of the profession toward its highest ideals.

Unfortunately some of the engineering schools appear to be motivated primarily by competitive considerations. They are fearful of losing enrollment. If students first take a pre-engineering college course, the half-qualified and the half-hearted may change their minds or may be eliminated before they reach the engineering school. Apparently these engineering schools prefer the present picture of enormous classes in the first year or two, cluttered with students who will never make the grade, with the resulting lowering of educational standards and the retardation of the better qualified.

Some engineering schools argue that their curricula now have a sufficient content of liberal courses, claiming that only about 50 per cent of their four-year curriculum is engineering. I maintain that, in the present stage of advancement of engineering science and progress, a thorough mastery of the fundamentals of the basic engineering sciences with an introduction to the applied problems of professional practice cannot be adequately covered in two years of a four-year course.

In the opposition by engineering schools and their spokesmen, much of their presentation revolves about the use of the word "culture." This is a tricky word, and its equivocal use serves but to confuse and obscure this discussion. I am avoiding the use of this word, and I ask those who discuss this subject to do likewise. The point I want to make is that *the present education of engineers*

is lacking in the humanities, and that *the average engineering graduate is an illiterate in the fields of economics, philosophy, history, the arts, and the social sciences.* We cannot give more of these to the engineering student and maintain the necessary content of professional education without, in some way, lengthening the period of educational preparation. I believe that the engineering schools now recognize that this is bound to come. They, however, are maneuvering to have any such lengthening take the form of additional years in the engineering schools. I am convinced that this would defeat the purpose, since the additional years would principally promote advanced graduate courses and technical overspecialization, and the desired broadening of the educational foundation would be neglected. Moreover, to avoid narrowness of viewpoint and of approach, the student in his formative years should have "a reasonably large access to other types of personality, other domains of knowledge, and other types of thinking than engineering." That is why I am fighting, almost a single-handed fight, to set the tendency in the direction found most desirable and effective by the other professions instead of letting it take its course in the direction desired by those engineering schools that are motivated chiefly by considerations of competition and enrollment.

In addition, through force of habit of years of propaganda in competition with liberal arts colleges and other non-engineering schools for enrollment of high-school graduates, our educators continue to expound the superiority of an engineering education, its "cultural" value, and its preparation for high positions in industry. I am not here discussing the relative values of liberal college education and engineering education. I submit, however, that *a combination of the two is superior to either alone as a preparation for professional lifework.* If this principle is accepted—and I do not see how it can consistently be challenged—then my thesis is proved.

The engineering education should be given by engineering educators in the engineering schools. The liberal college education should be given by college educators in the colleges of liberal arts and sciences. For the engineering educators to claim that they are the best authorities on both and that both should be entrusted to them is sheer egocentric presumption. The medical schools and the law schools do not dream of competing with the colleges of liberal arts or of usurping their province.

The engineering educators preach that "an engineering education is valuable even for those who are not going to be engineers." To this I add that *a liberal college education* is valuable even for those who *are* going to be engineers. All true education has its values, for which it should be given credit.

The engineers who have taken "arts college" work before entering engineering school are virtually unanimous in endorsing the value of this educational preparation. Many of them, and many others who have not had the advantage of this superior preparation, are following this procedure for their sons.

A larger proportion than is generally realized of successful engineers and leaders of the engineering profession have gone through such training of their own initiative, with liberal arts college education preceding their engineering training or practice. I submit here two partial lists which speak for themselves. They have been compiled more or less at random from such sources of information as happened to be readily available, and are arranged approximately in chronological order. These lists are naturally far from complete, and for any errors of omission or commission I apologize in advance. The array of names is, I believe, impressive.

1. *Outstanding Engineers Who Had Pre-Engineering College Education*

General George W. Goethals—Builder of the Panama Canal.

William Barclay Parsons—Chief Engineer, Rapid Transit Commission; Consulting Engineer, Panama Canal.

Dr. Gano Dunn—President, Cooper Union Institute of Technology; Past President, United Engineering Societies.

Dr. L. B. Stillwell—Past President A. I. E. E.

Dr. Otis E. Hovey—Consulting Engineer; Honorary Member, Am. Soc. C. E.; Director, Engineering Foundation.

Alfred P. Sloan—Chairman of Board, General Motors Corporation.

Dean Charles Derleth, Jr.—University of California; Consulting Engineer on bridges and tunnels.

Robert Spurr Weston—Past Chairman, Sanitary Engineering Division, A. S. C. E.

Dr. Wilbur J. Watson—Eminent Bridge Engineer; Designer of the Goodyear Zeppelin Dock at Akron.

Dr. C. C. Williams—President, Lehigh University; Past President, S. P. E. E.

Dr. John Lloyd Newcomb—President, University of Virginia.

Prof. Hardy Cross—Yale University—Authority on Structural Engineering.

Col. F. W. Scheidenhelm—Consulting Hydraulic Engineer; U. S. Distinguished Service Medal.

Clifford M. Holland—Designer and Chief Engineer of the Holland Tunnel.

Karl R. Kennison—Chief Engineer, Metropolitan District Water Supply Commission (Boston).

E. A. Mees—Asst. Chief Engineer, Federal Power Commission.
Ralph J. Reed—Consulting Engineer; Past President, National Council of State Boards of Engineering Examiners.
Jonathan Jones—Chief Engineer, Bethlehem Steel Co.; Chief Engineer, Detroit Bridge.
George W. Burpee—Past President, Amer. Inst. of Consulting Engineers.
Edward J. Mehren—President, Portland Cement Association; Former Editor, Engineering News-Record.
Allston Dana—Engineer of Design, Port of New York Authority.
Prof. Hale Sutherland—Lehigh University.
Senator Thomas C. Desmond—President T. C. Desmond & Co., Engineers and Contractors.
Prof. Harold A. Thomas—Carnegie Institute of Technology.
Harold M. Lewis—Engineer and Planning Consultant, Regional Plan Association.
Charles Mayer—Consulting Engineer; Designer of Lewisohn Stadium.
Dean Thorndike Saville—New York University; Authority on Hydraulic and Sanitary Engineering.
Gavin Hadden—Past Vice President, Amer. Inst. of Consulting Engineers.

2. *Outstanding Engineers Who Had Complete Liberal Arts Education and No Formal Engineering Education.*

(The first 5 men in this list studied before engineering schools were available. This, however, does not detract from the fact that their general college education proved an excellent foundation for their distinguished professional careers.)

John Stevens—Pioneer American Mechanical Engineer.
James Renwick—Eminent Engineer, Scientist, Educator.
Horatio Allen—Pioneer American Canal, Railroad and Mechanical Engineer; Past President, Am. Soc. C. E.
Alfred W. Craven—Chief Engineer, Croton Aqueduct Commission; Past President, Am. Soc. C. E.
Prof. William Gillespie—Head of Civil Engineering Department at Union College.
George S. Morison—Eminent Bridge Engineer; Past President Am. Soc. C. E.
Dr. Holton D. Robinson—Eminent Bridge Engineer.
W. S. Kinnear—Builder of Detroit River Tunnel; Past President, Amer. Inst. of Consulting Engineers.

Dr. Charles F. Scott—Eminent Educator and Electrical Engineer; Past President S. P. E. E., A. I. E. E., E. C. P. D., N. C. S. B. E. E., etc.

Edwin F. Wendt—Interstate Commerce Commission; Past President, Amer. Railway Engineering Association; Past President, Amer. Inst. of Consulting Engineers.

Dr. W. H. Coverdale—(Coverdale & Colpitts, Consulting Engineers)

Jerome Alexander—Eminent Consulting Chemical Engineer.

Prof. Charles A. Ellis—University of Illinois and Purdue University; Designing Engineer, Golden Gate Bridge.

Harry A. Hopf—International Authority on Management Engineering.

In running through the names in both of the foregoing lists, the outstanding impression is *leadership*. Where pioneering, resourcefulness, invention, human relations, administrative ability, management, vision, and professional leadership are involved, a broad educational foundation appears to be a splendid preparation for an engineering career. If the engineering profession is to be a profession in the highest sense of the word—*a profession of planners and leaders and not of mere technicians*—the answer is indicated. We need education, and not mere technical training; and, generally speaking, *education should precede training.*

My picture of professional preparation is that of the pyramid: First, as a broad base, the education that all educated men should have; then the basic courses that all engineers should have; and, finally, the more specialized training for the major branch of engineering selected.

The logic is that of progressive preparation and specialization, with advancing intellectual maturity for decisions affecting choice of lifework and for the more intensive preparation therefor.

The only remaining argument of the opposition is that of the hardship on the poor student who cannot afford to add two years to his educational preparation for an engineering career. This argument is a confusion of issues. We are discussing a proposal *to encourage* pre-engineering college study, *not to make it mandatory.* We want to encourage and stimulate this improved preparation for those who can afford it, and for those who have the aptitude, ambition and character to secure it for themselves despite poverty. (Most of the men in the foregoing lists of engineers who had a pre-engineering college education as a foundation for their careers were sons of poverty, not scions of wealth.) We want to make the goal —*the engineering profession of the future*—a sufficient incentive and reward to justify this additional investment and sacrifice! We

cannot attain this goal until this improved educational preparation becomes more general.

How can we encourage more young men to take this improved educational preparation? The only solution I can offer is *to recognize pre-engineering college education by making it permissive for the State Board of Examiners to give fractional credit for such education.* For those who have invested such additional two years in desirable educational preparation, it is proposed to offer a partially compensating inducement in the form of two years reduction in the final apprenticeship requirement before admission to licensing examinations. In New York State, in effect, out of a 12-year experience requirement for non-graduates, we now give 8 years of experience credit for 4 years of study in an engineering school, and it is permissive for the State Board to give additional year-for-year credit for graduate study, with no minimum limit fixed for the residual experience requirement. Why then is it inconsistent to give two years of credit for two or more years of pre-engineering college study, if the latter is desirable professional preparation? In justification of such reduction of the internship requirement, I submit that the more mature and better equipped students entering the engineering schools will be more intensively benefited during their period of engineering study, and will in the same measure be better prepared to profit more intensively from the subsequent apprenticeship period. Some men, as is well known, can learn more from two years of practical experience on the job than other men can learn in four years of such experience.

There is nothing sacrosanct about the 4-year period for the experience requirement; otherwise the present permissive year-for-year credit for graduate study would have to be expunged from the law. The 4-year figure is arbitrary, and is out of line with the requirements for admission to the other professions. There is no logical reason why it must be 4 years, rather than 3 or 2. It is a vestige of the earlier apprenticeship tradition of the profession, which has been superseded by the present educational picture. The total experience requirement is best regarded as a reserve of credits to encourage desired educational preparation. It is not a question of equivalents, but rather of alternatives. The determining criterion should be the ultimate good of the individual and of the profession. In the long run, it matters little to the profession if an individual, after completing his professional education, is admitted to the licensing examinations two years earlier or two years later. The encouragement of superior educational preparation is far more important to the future of the individual and of the profession.

It has been most heartening to find that many leading engineers and educators are equally convinced of the desirability of pre-

engineering college education. That I am not alone in these convictions is evidenced by the following brief excerpts from opinions recorded by others on the subject:

Dr. Gano Dunn: "I have always been a strong advocate of a fundamental liberal arts education as a prerequisite for an engineering course. . . . It is almost essential if an engineer expects to become an important factor in his profession."

Senator Thomas C. Desmond: "You can quote me at any time as heartily approving of the belief that two or more years of pre-engineering collegiate training will be of great benefit to prospective engineers, as improved preparation for their professional lifework."

Jonathan Jones (Chief Engineer, Bethlehem Steel Co.): "I believe that in future those who are going to really lead in engineering will be those who have had this broader training, and that those who take only a four-year engineering course will be under a handicap."

Professor J. K. Finch: "In my opinion, the most promising plan to meet all our engineering educational problems is to be found in the development of the pre-engineering idea." . . . "I am confident that the two-year pre-engineering plan is sound, that it is a plan toward which our better engineering schools are slowly moving and that it will strengthen the general standing and broaden the outlook of our profession. . . . The Registration Law should encourage it."

Professor Hale Sutherland: "You are on sound ground in urging that engineering education be advanced to the graduate level."

Dr. W. E. Wickenden (President, Case School of Applied Science; Past President S. P. E. E.): "While preliminary study in an arts college seems fairly certain to be voluntary for prospective engineering students, it may well be encouraged more widely for the sake of its personal and cultural values."

Arthur V. Sheridan (Commissioner of City Planning, New York City; Past President N. S. P. E.): "Surely there can be little question of the necessity for a thorough general academic training for any professional man. The Engineer must be articulate and capable of contending on an equal basis with the representatives of business and the other professions in helping to direct community progress and the affairs of government. Two years spent in an intensive study of general mathematics, history, literature, philosophy and at least one foreign language is none too much for the average man to prepare himself for professional matriculation."

Dr. George F. Zook (President of the American Council on Education): "Engineers must realize that they live as members of society, not merely as professional technicians. They need more cultural studies. Medicine and Law recognize this by requiring two years of pre-professional collegiate training."

Gavin Hadden (Consulting Engineer): "I am convinced that he has a better chance of becoming a good engineer, and one who will be a credit to the profession, if he takes a college course first."

Prof. Sumner B. Ely (Carnegie Institute of Technology): "Men who study in one field only become highly specialized and narrow. . . . Such subjects as literature, history and the like round out the student and help greatly in developing his character, show him how to get more out of life, and interest him in human affairs and make him a better citizen generally. . . . Breadth of knowledge is necessary in the engineer, as well as technical information."

Prof. John J. Caton (Founder and Director of the Chrysler Institute of Engineering): "I feel that before long a pre-engineering education will be required. It gives the candidate four years after leaving high school to get his feet upon the ground, to push his border lines back, and to make a decision that is vital to him at a time when his mind is more mature. During this four-year cultural training, he has acquired poise, carriage, approach and attack,—which are very conspicuous by their absence in engineers. . . . If an engineer had no ambition other than to become a good technician, then I would say his education is adequate."

Prof. Hardy Cross: "I am committed to the thesis that there is no substitute for a good general education in any walk of life. . . . Some years ago I remarked that I believed I had probably learned as much engineering out of a Latin grammar as I had out of an engineering text. I think you will understand what I meant in saying that I there learned accurate definition and accurate classification."

George W. Burpee (Consulting Engineer): "The purpose of education is to fit a man to be at home in the world. The traditional college is dedicated to this purpose and, in my opinion, in its non-commercial atmosphere, performs this function more effectively than the professional school which, be it law, medicine, or engineering, is necessarily concerned chiefly with providing the student with tools whereby to earn his living. An engineer today is a very important member of society, and it is most important that he acquire a philosophy; and, because I believe that such a philosophy is more readily to be obtained by education in the humanities, I am heartily in favor of such education in advance of professional training."

President Philip C. Nash (University of Toledo): "No other profession, such as law, medicine, teaching, or the ministry, dreams of giving so narrow a preparation for life. Are we justified in giving it to engineers?"

E. J. Mehren (President, Portland Cement Association; Former Editor, Engineering News-Record): "Such a preliminary education should enable a student to get the most out of an engineering course and, through the development of the imagination, push him into truly creative work, into steps that others do not so much fear to take as never think of taking. Looking to one's social responsibility, such preparation is more necessary today than ever before in the engineering age."

Col. F. W. Scheidenhelm (Consulting Engineer): "I can hardly use terms to express my advocacy too strongly. I consider such preparatory Liberal Arts education to be a factor which, more than any other, is likely to lead to a broadening of ability and of sphere of activity beyond the narrower technical confines."

Prof. George C. Ernst (University of Maryland): "Such a training . . . would supply much needed additional time in the professional years. This objective is not likely to be accomplished by purely voluntary means. Those states with license laws could aid materially by legislation."

Allston Dana (Engineer of Design, Port of New York Authority): "It is preferable to put this time into general college work rather than into post-graduate engineering studies. . . . He comes to his engineering studies with a more mature mind and his technical training is, for that reason, more thorough."

Carlton S. Proctor (Consulting Engineer; Director Am. Soc. C. E.): "Is it not time we should agree that a professional man cannot be produced in four years, but that an accredited civil engineering training must be definitely postgraduate, with a broad undergraduate training as a prerequisite? . . . Only by making our profession worthy of 'status' can we attain our aims." "I do hope that all professional agencies will pull together for the accomplishment of this objective in the improvement of engineering education, which is obviously an essential immediate step to the preservation of the profession."

Conclusion

The present inadequate preparation of entering students, lacking in many instances even such obvious elementary requirements as High School physics, results in a deplorable waste of valuable time, lowering of standards, and retardation of progress in the professional schools. Pre-engineering college education will supply students better equipped and prepared to benefit from an intensive 4-year professional curriculum.

The content of engineering knowledge now available and required for practice in any one branch of the profession has grown enormously in the past fifty years. With the standards of education rapidly increasing for men in all walks of life, shall engineering education remain at the level of fifty years ago? Pre-engineering college education will raise the level of education in the engineering schools, and will free the present crowded four-year curriculum for higher intensive professional education without waste of time to make up for deficiencies of high school preparation and without diversion of time to teach elementary non-engineering subjects that can better be taught elsewhere.

The other learned professions have reached the conclusion that a solution of these problems requires two or more years of study at a college of liberal arts before enrollment in the professional schools. Is there any valid reason why engineers should require less education or a narrower education than physicians and lawyers? Shall the education of engineers continue as a technician's training or shall it be raised to a truly professional level?

The highest and broadest interests of public welfare and social progress are not best served by mere technicians whose schooling has been confined and limited to the technical without the development of social perspective, character and intellectual breadth through an adequate foundation of liberal education. With such preparation, the student will be better equipped to profit from an intensive professional training, to find his place in industry after graduation, to continue his self-education thereafter, and to give his professional leadership to society.

Is it not time for the engineering schools to stop competing with the colleges of liberal arts for enrollment of high school graduates? Let each perform the function and occupy the place for which it is best fitted. Let the general college complete the educational preparation of the student before his enrollment in the engineering school for intensive professional training. Propaganda and enrollment competition are not in harmony with the highest educational ideals. To keep on repeating, parrot-like, that "Engineering is a culture" and that "Engineering is a splendid education even for those who are not going to be engineers" is not a sincere and open-minded answer to the problem.

Our chief concern should not be competition for enrollment but rather the best ultimate interests of the individual student, the profession, and the public. We want the best possible education for the engineer of the future, and that means the education of a professional man and not that of a mere technician. We want the profession of the future to be a profession of planners and leaders, with higher standards and standing founded on superior educational preparation. And we want to equip the engineers of the future, through such superior educational preparation, for the highest leadership and service to society.

THE BEGINNINGS OF ENGINEERING EDUCATION *

By THOMAS T. READ

Vinton Professor of Mining Engineering, Columbia University

The generally accepted view of the beginnings of engineering education is that civil engineering was an outgrowth of military engineering which, after the "revival of learning," acquired an educational aspect of its own. W. E. Wickenden has ably summarized this view and says † that Perronnet, who was chief engineer of bridges and highways under Louis XV, "was certainly the father of engineering education," with France as the birthplace. The purpose of this paper is to present the unorthodox view that technical education, in which engineering is included, had its practical beginning in connection with the mineral industry, and that Germany, not France, was its country of origin.

To support this thesis it will be necessary to review briefly what is known of the history of mineral technology in Europe. Oriental, including Arabic, culture is omitted because I believe that it had little influence on modern developments except through Greek and Roman contacts with it. Greek literature throws but little light on the mineral technology of that time because several of the works on that subject have disappeared. Because of Pliny we have a somewhat more adequate picture of Roman technology, but the easily accessible written record ends with the early centuries of the Christian era. George Bauer's "De Re Metallica". (1556), based on his study at Joachimsthal in Bohemia and Chemnitz in Saxony, takes up the story more than a thousand years later. Even a hasty comparison of this with the earlier works reveals that tremendous technical advances had taken place in the intervening period.

It is possible, of course, to believe that all this advance took place between the beginnings of the "revival of learning" and the sixteenth century, but there is a considerable quantity of little known material which not only does not support that view, but seems rather effectively to refute it. Hardanus Hake's "Die

* Presented at the 47th Annual Meeting, S. P. E. E., Pennsylvania State College, June 19–23, 1939.

† "A Comparative Study of Engineering Education in the U. S. and Europe," by William E. Wickenden. Bull. 16. Investigation of Engineering Education, S. P. E. E., 1929, p. 9.

Bergchronik," which apparently was written in 1581–3 but of which nothing more than excerpts were published before 1911, deals with the history of mining in the upper Harz district from the tenth through the sixteenth centuries. A critical study of this and other early works by H. Boyce * accepts the view of Schmoller † that no connection can be established between Roman and German mining, and sets forth that the Rammelsberg mine, at Goslar in the Harz, was opened before the end of the tenth century, the miners being men of Frankish stock whose place of origin is not known. The mines of Styria, Salzburg, and the Tyrol had been worked even earlier. The dates given by George Bauer ‡ in his "De Veteribus et Novis Metallis" (1546) confirm these, and he adds that the mines at Schemnitz, Hungary, were worked before 750 A.D. The evidence seems strong that there were no "Dark Ages" in the mineral industry; mineral technology was continuously advancing in Central Europe.

One possible reason for this appears when we recall that the economy of both the Greeks and the Romans was based on slavery. Where slaves carry on technical operations the almost inevitable result is that it is not long before it is only the slaves who know much about the technology. John Mawe, in his account of his travels in Brazil about 1810,§ tells how the slave owners there knew nothing of the technology of mining, brick-making, etc., and he was invariably referred to a negro slave for the answers to his questions about them. Roman and Greek mining operations were performed by the native people of the regions over which they had acquired political control. When that control ended the natives ceased the work if they had no personal need for its products and could not use them for trading purposes, but there must have been many places where they not only kept on with it, but continued to improve on the techniques.

European technology in the early Middle Ages therefore does not represent a fresh impact of Mediterranean culture on the center of the continent, but is rather the flowering of an indigenous technical culture that had steadily been developing. Whether Schmoller is right in believing Central Europe owed no debt to an early Roman influence would be hard to prove or disprove. Its

* "The Mines of the Upper Harz from 1514 to 1589." Dissertation for the doctorate. Dept. of History, University of Chicago, 1920.

† "Die Geschichtliche Entwickelung der Unternehmung." *Jahrbuch für Gesetzgebung*, XV, 675.

‡ Most of the historical information in this not easily accessible work can be found in the footnotes to H. C. and L. H. Hoover's translation of the "De Re Metallica."

§ "Travels in the Interior of Brazil." John Mawe, 2d Edition, London, 1821.

greatest debt unquestionably was to the native intelligence of the people of the regions where the progress was being made, who, because of the incessant migrations, may have come there from some other area. The reason why we have so little early record of this technology is because, as Hake points out, the scholars did not know the terms used by the miners and smelters. It will be recalled that "De Re Metallica" was not published in an English translation until more than 350 years after it first appeared because Bauer, a physician financially and intellectually interested in the mineral industry, had coined his own Latin equivalents for these terms, and German and Italian translators had made a sad mess attempting to understand them.

The silver-bearing lead deposits of Freiburg, in the Erzgebirge (the mountain range between Saxony and Bohemia), were discovered about 1170, according to Bauer,* by carters who were hauling salt from Halle into Bohemia and who recognized the mineral when it was exposed in the ruts of their cartwheels. Samples taken back to Goslar showed that it was so much richer in silver than the lead ores of the Harz region that an immediate migration to Freiberg took place. The result of the success of mining operations there was, as Papperitz † has pointed out, that mining was the most highly developed technology in the sixteenth century, and Freiberg was the Athens of that kind of culture. Papperitz does not say, what he probably knew, that the handling of the water in the mines of the Harz and Erzgebirge regions was always a critical problem and the object of the best engineering talent of the time. It will be recalled in this connection that the immediate practical application for the engines of Savery and Watt at the beginning of the eighteenth century was for pumping in the mines of Cornwall.

Prior to 1700 young men had been coming to Freiberg from all over Europe to study technology as practiced in the neighboring mines and metallurgical plants, because it was there most advanced, and nothing regarding it was taught in the universities of that time. This was costly in both time and money, and the knowledge thus acquired was not systematically organized. In 1702 Oberberghauptmann Abraham Von Schonberg (whose name indicates he was probably not an "Aryan"), persuaded the authorities to establish a system of free scholarships for natives of Saxony who would pledge themselves to enter the state service. He undertook, if this were done, to give the systematic instruction his

* "De Veteribus et Novis Metallis." See footnote 11, p. 36, of Hoover's translation of "De Re Metallica."

† "Gedenkschrift den hundert und fünfzig Jubilaum der K. Sachs." Bergakademie zu Freiberg. Erwin Papperitz, Freiberg, 1916.

personal supervision, and it was so established. It should be noticed that this was not instruction given in a school, but a training course given in the mines and metallurgical plants. The Tata steel works in India has maintained a similar arrangement for some years. The "loop" courses given by Bethlehem Steel, and other companies, are different in that they take older students who have already had a technical education.

From this first technical training course there developed, in 1712, a local demand to establish at Freiberg an "Augustus-Universitat"* in which assaying and mining and metallurgical technology would be taught, as well as chemistry and physics. Nothing resulted from this until 1765 when the regent, Prince Xaver, was persuaded to set aside a fund for establishing a mining school and hiring instructors. This Bergakademie at Freiberg began work at Easter, 1766, and its subsequent history is well known.† For a long time it was one of the foremost institutions of the world in the field of mineralogy, geology, and the applications of chemistry and physics to mineral technology.

Meanwhile an ambitious development of mining schools had taken place in Russia. Peter the Great, the ally of Frederick Augustus in the Twenty-one Years War with Sweden, had been active in introducing European learning and technology into Russia. He started, in 1709, a school in connection with the Nevia iron works that, so far as the records reveal, was of primary grade. It was evidently intended to be the bottom rung in a system culminating in a technical institution of collegiate grade. More were established at other works; that established at Ekaterinburg in 1722 was later raised to high-school grade. In 1773 a law was passed establishing a School of Mines at St. Petersburg and, in plan at least, the organization was then complete of a graded system of schools, for persons of noble birth, intended to train them to exert effective administrative and technical control over the mineral industries of Russia. This general plan was adhered to for more than a century, producing, at least in theory, an organization of 100 primary schools, and 10 middle schools leading up to the central mining school at St. Petersburg.‡ In the higher schools, at least, instruction was on a high plane, though it apparently was always more interested in the theoretical than the practical aspects of knowledge in this special field. The mining schools of Russia need not detain us here, for there is no clear indication that many foreign students ever attended them, or that they ex-

* Frederick Augustus, then Elector of Saxony, had also become King of Poland in 1697.

† Papperitz, loc. cit. See also Festschrift zum hundertjahrigen Jubilaum der K. Sachs. Bergakademie, Freiberg, Dresden, 1866.

‡ After 1896 this was known as the Mining Institute of Catherine II.

ercised an appreciable influence on the development of mineral industry education in other countries, other than what bearing they may have had on the decision, at Freiberg, to change from a works training course to a technical school.

The Empress Maria Theresa took a great interest in education and the industries of her native land, Hungary, and through her support an Imperial decree, dated June 13, 1763, directed the establishment at Schemnitz of a "bergschule." It began work with only one professor, Nicholas Jaquin, was not really well established before 1770, and early became a forestry as well as a mining school, so it is open to argument as to whether it or Freiberg was the first technical mining school. Gustav Faller has published * a history of this school. It seems probable that the Imperial decision to establish it may have been an important factor in inducing Prince Xaver to put the work at Freiberg on a regular academic basis, but aside from that it seems to have had no marked influence on mineral industry education, since the quality of its work, while high, seems always to have been below that at Freiberg.

There are various obscure references in literature to provision for mineral industry education in Italy in this early period, but I have not been able to find anything definite on the subject. After the fall of the Roman Empire mineral technology declined in the area of the Italian states, while it continued to advance in the middle European regions. Possibly this is a major reason why interest in the Italian centers of learning was in pure science rather than in its practical applications, especially in the mineral field. It is true that Vannuccio Biringucci's "De la pirotechnia," which appeared in 1540, antedates "De Re Metallica" by sixteen years and seems to indicate that Bauer borrowed what he says about iron smelting from it. Bauer's personal interest was in the mining and smelting of lead ores for their precious metal content. Neither of these two authors attempts to tell much about the technology of iron, and what they say is difficult to understand. Without prolonging the discussion, it may be accepted that Biringuccio's work throws no doubt on the previous statement that mineral technology during the preceding centuries was more highly developed in central Europe than it was in the Italian states.

Of the mining school (bergschule) at Tarnowskie Gory, Poland, the director of the Unia Polskiego Przemyslu Gorniczo-Hutniczego at Kattowice says, in a recent letter, that "This very old institution—in fact, one of the oldest mining schools in the world—was created in 1581, and organized scientifically in 1803." I have no

* "Geschichte der K. Berg- und Forstakademie in Schemnitz." Gustav Faller. Schemnitz, 1868.

other information about this institution and it seems reasonable to conclude that it was, before 1800, only an ordinary school, with perhaps some attention to a local mining industry.

Returning now to the school for draftsmen which Perronnet started in his office in Paris in 1747, forty-five years after von Schonberg began mining instruction at Freiberg, it will be recalled that the name of Ecole des Ponts et Chaussées was not bestowed on it until 1775, and by that time the Bergakademie at Schemnitz had been in existence for twelve years, that at Freiberg ten years, and the mining school at St. Petersburg two years. If the attempt in 1712 to found a University at Freiberg, in which mineral technology would be taught, had been a success we might have had our first engineering school within a university more than a century before Scottish and American ones knew any such relationship. The University at Leipzig was then already 300 years old, and Augustus' major interest was in developing his capital city of Dresden, only twenty miles from Freiberg, so it is perhaps not surprising that the proposal came to nothing.

It seems idle to speculate how different the development of technical education at a university level, which in Europe typically took place separately from the universities, would have been if the institution at Freiberg had been organized as a University instead of a Bergakademie. The present technical university at Charlottenburg developed out of the bauakademie established there in 1799; the School of Mines founded by Columbia College in 1864 became a school of general technology within a few years (though long retaining its original name), and gave rise to university departments of geology, botany, and zoology, as well as greatly strengthening the departments of chemistry and physics. The School of Mines founded at Kimberley, South Africa, in 1896, became, through successive changes, the University of the Witwatersrand in 1921. Possibly it does not greatly matter how technological education develops, so long as it eventually attains its objectives.

THE PRACTICE AND TEACHING OF ELECTRICAL DESIGN *

By T. C. LLOYD

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Some years ago a professor of English made the remark that a very successful conspiracy existed on the part of all of his colleagues, a conspiracy to prevent any college student from ever desiring to read Shakespeare.

Would it be too much to say that a corresponding aim exists with regard to teachers of electrical design? It is very likely that a questionnaire sent to former electrical engineering students, asking them what they learned in their electrical design course would be echoed rather unanimously by the answer once given: "I learned that I do not want to be an electrical designer."

This reaction has produced its inevitable effect, and through continued lack of enthusiasm for design courses on the part of students and graduates, coupled with demands on the curriculum for other types of courses, electrical design as a requirement has disappeared from nearly all engineering colleges. In some it is offered as an elective, and usually in a rather emasculated form.

Looking back on electrical design courses as taught, and recalling their content, it is probably as well that they are nearly extinct. Yet if this continues, from whence will the future supply of electrical designers arise? In fact, from whence is the present supply coming?

I have been asking that question of deans and engineering professors for some time. Some reply with ill-concealed surprise at my naivete. "Employers do not want us to teach design; they will train our graduates along such lines. Besides there is no use in teaching design, a man is born with or without that sort of ability and the employer will sort them out." There is just enough truth in those statements to make them especially invidious.

Large electrical manufacturers do prefer, after a process of more general training, to teach their engineers their own design methods. Yet for every one such company there are dozens of smaller concerns employing from one to a score of design engineers (using their own individual design processes), who might not be

* Presented at the 47th Annual Meeting, S. P. E. E. (Electrical Engineering), Pennsylvania State College, June 19–23, 1939.

adverse to hiring graduates acquainted with the fundamentals of design. Yet these smaller companies are not so vocal; and no one of them hires a large enough group of graduates at any one time to make his requirements felt.

As to designers being born as such, so are marriages made in heaven. Arnold Bennett, in commenting on this latter statement, added that divine providence was indeed remarkable in locating our heaven-sent future mates in the same neighborhood or in the same circle of friends with ourselves! Consider the chance entering into the selection of a job by a college graduate and the whims that direct him from one employer to another. Are we to believe that again nothing but an all-kind providence enabled this born designer to finally end in a position where he and his equally guided kind have had the privilege of designing the millions of electrical gadgets which have been marketed in the past two decades?

The truth of the matter is that most designers are ordinary engineers, ranging from high to low degrees of ability, and possessing only the special gifts of being able to see electrical constants in physical dimensions and of solving machine analyses "in reverse." On these latter points more will be said.

It is true, in part, that electrical design is somewhat of an art rather than a science. In so far as a number of the designer's decisions are based upon experience and judgment, rather than calculation, electrical design is an art—but only as practiced by the experienced designer. One by one, the items of design which had previously been determined by guess (reinforced by judgment) have yielded to analysis. Because of this a novice in the field with little or no experience to fall back on, must determine more items by calculation than his experienced co-worker.

For some months I have been quizzing design engineers. Did you take a design course in college? Did you like it? Did you ever intend to be a designer? The answers are not surprising. Few of the more recent graduates had such courses. None of those who did expressed any enthusiasm. With few exceptions they had never expected to be design engineers. And all of them, with or without college design courses, commented on the fact that they had never had the slightest inkling of the real nature of electrical design. Now when a group like this is satisfied with its present occupation and yet disliked the academic presentation of it, there are two possible explanations. One is that their personal tastes changed after graduation, and the other is that a wide gulf exists between the teaching (and the academic conception) of electrical design and its practice. The latter conclusion is not complimentary to engineering faculties but it is almost inevitable.

One of the surprising things about electrical design courses has been that they have been taught chiefly in one form.* That is, in attempting to put across the fundamentals of this subject in the classroom the instructor has nearly always put his money on one horse; after losing consistently he quit the track rather than back another.

To illustrate, suppose we consider the teaching of induction motor design. After general preliminaries, some very broad specifications are given the student and he is expected to design a motor to meet them. He calculates some of the major dimensions, and then proceeds in laborious detail to design his punchings, down to the last dimension, coincident with the design of the windings. Three months later he is ready to calculate performance. Following the usual procedure, the motor so designed may display almost any sort of values for maximum torque, starting torque, or full-load slip. His specifications have not been difficult to meet, nor has the procedure followed enabled the student to design directly for the desired characteristics. This, and every other type of machine which the student may be called upon to design, has involved a tedious process crowded with detail. It is a rare student who can grasp any fundamental principles or obtain a clear picture of what he has done when this orgy of detail is finished.

This should be condemnatory enough for the process, but equally unsatisfactory is the fact that the procedure of design as taught is always an artificial one, which has not been followed in a design office in years, and by which no modern machine could possibly be designed to sell in the present competitive market. Still, a teaching process need not be frowned upon if it does not follow commercial practice, provided the artificiality has resulted in clarity of principle and purpose. Yet this process, resting on the requirement that the student design all of his machine parts, has instead, confused the novice.

Before attempting to make any suggestions as to methods of teaching electrical design, let us first see what has happened in the industrial field, and the functions of the electrical designer. (The motor industry will be stressed as illustrative.)

Progress in Design

Improvements in electrical design methods have brought about changes which can be grouped roughly into three classes.

* No attention will be paid here to the new method of teaching electrical design by permitting the student to spend a semester (or even two!) in building some gadget like a rheostat. This is usually a mild anesthetic for ridding the instructor of a troublesome student, and should be classed with oral penmanship.

1. The first might be called an experimental stage, wherein the "designer" had no preconception of the results to be expected from his finished product until it had been built and a test run was made. If the designer's field was with induction motors, their successful operation was cause for congratulations, for all too often these machines (and other types as well) failed to operate satisfactorily when built. Such failure required expensive reconstruction, or perhaps the complete abandonment of the motor and a fresh start.

2. The first improvements in this situation came about through the development of machine analyses, that is, mathematical expressions involving power, torque, speed, with calculation processes for losses, or graphical representations of performance as represented by the circle diagram of the induction motor. Their use led gradually into the second stage of design progress, wherein the designer's procedure was somewhat modified. Again he would lay out the drawings for the machine, designing the laminations and selecting a trial winding. But now before these drawings would be released for construction, he would calculate the machine constants and predict the performance. If such "paper checks" showed an unsatisfactory machine, he started again, modifying his windings, lamination dimensions or what not. Once modified, he again predicted performance, repeating this process until a satisfactory design resulted.

There are two points to observe in this second stage of design progress. First, that it was a great step forward in manufacturing economy as it saved the construction of a machine which might prove of no value, second its application presupposes that the designer is able to predict the machine constants while it is still on paper. Before this advantage could be obtained a great amount of pioneering work had to be done. Many of the early formulas developed for such work were crude and inaccurate, others were surprisingly precise. The elimination of much cut-and-try construction was brought about by such formulas and all modern electrical design leans upon them heavily. Although trial and error were eliminated from construction it was not eliminated from the designer's work until the third stage of design progress was reached.

3. In practice, rigid specifications are often set for performance. Suppose in the case of the induction motor that the particular item of performance with which the designer expected some difficulty was the maximum torque. As previously described it would be necessary for him to assume a winding, calculate the constants, and then the maximum torque to be expected. The necessity of repeating this calculation could be eliminated, if it were possible for him to use the usual formula for maximum torque, so modified that

it could be solved directly for the winding which must be used. That is, instead of substituting machine constants in a formula and obtaining performance, the third stage of design progress is achieved when the designer can substitute required performance items and obtain construction constants.

This final stage largely eliminates trial and error from the designer's paper work. The design of all types of electrical machines has not reached that third and final stage of progress. Several are still in the dark ages, requiring construction and test before the designer knows whether he has a satisfactory machine. Other common types are in the second stage. It is difficult to draw sharp lines of demarcation, for on the same machine it is sometimes possible to design for one given characteristic and be unable to do more than guess at others.

Intramural and Extramural Standardization

Suppose that a manufacturing concern has just designed and built its first motors. They are now ready to design another of say a different horsepower and speed. It does not take great cleverness on the part of an engineer to realize that the second rating could be produced more economically if the same frame, end heads, bearings, and stator and rotor laminations, could be used in the second motor as were already constructed for the first. This process grows naturally until it has a profound effect upon the whole problem of electrical design. That is, the designer knows that his factory has patterns, tools, dies, and all of the rest of the mumbo-jumbo of modern manufacturing methods whereby they can construct motors of certain physical sizes. Faced with a certain set of specifications and rating, his problem is one of determining in what particular frame, and of what particular parts, the motor should be built.

Or, given a certain motor frame, what horsepowers and speeds can be built in that frame economically? He cannot layout a new frame and set of laminations for every motor he designs; this would soon bankrupt his employers.

The obvious result is a line of standard frames and laminations, standard, that is, with any one motor manufacturer. It is up to the designer to fit any motor of given specifications into such frames, using the parts that match the construction.

All of this represents standardization, an "intramural" standardization, brought about by any one motor builder within his own manufacturing facilities. But in the industry as a whole, and to the motor user, up until recent years the picture was chaotic.

The purchaser of motors may have designed his machine about the motor obtained from Company A. If, for any reason, he should

desire to obtain a different source for his motors, he might discover that for the same speed and horsepower, the motors of B were longer, had a different shaft diameter, different mounting dimensions, and widely different standards of performance. The user had two alternatives, one was to pay a premium price to B for him to design and build a motor similar to A; the other was to redesign his own equipment. Either might prove to be an expensive procedure.

The obvious answer to this was standardization within the motor industry as a whole, the development of a standard line of frames in which mounting dimensions, height of shaft above base, and shaft sizes should be the same for any one frame size regardless of whether it was manufactured by A, B or Z.

Such "extramural" standardization was a benefit to the motor industry and the motor buyer. The user could design his devices to take a certain frame size and be sure of wide sources of supply and prompt delivery; the motor manufacturer could now attempt to sell to all of his competitor's customers with much more freedom.

Effect on a Teaching Method

Progress in design methods and standardization have had profound effects on the technique of electrical design. Yet so far as can be learned they have had no influence at all on the method of teaching the subject. For some reason the academic conception of design seems to have "solidified" in the second stage of the art, wherein the student designer took, thankfully, the performance that came from his work and called it a finished job. The conception that certain items of performance must be met accurately, and a method whereby construction data could be solved for directly to yield that performance, has apparently not penetrated to our design classrooms.

Yet the effect of standardization, whether it be from within or without, has been still more far reaching. It means that a designer of a motor, generator or transformer is not concerned with the complete design of every item which goes into the machine construction. Once he has selected his punchings, the thickness of the stack, and the windings to yield a predetermined performance, his job is done. The use of standard parts has removed the last vestiges of drafting board work from the electrical design field. Nowhere in his whole procedure is there any of the lengthy, detailed and involved determination of every last dimension by the laborious process through which design has often been taught.

The point is stressed for this reason. The objections to design courses wherein they seemed to have wandered from fundamentals,

and into the highly specialized field, could be largely removed, by a consideration of electrical design as actually practiced. A change in the method of teaching electrical design, whereby machines are designed for rigorous specifications, *from parts available* could readily eliminate the months of detailed work spent in designing parts, and which only serves to confuse many design students.

Emphasis could be placed on two items of fundamental importance:

(1) The determination of winding or machine constants from physical dimensions.

(2) The modifications of the usual machine analyses (as presented in texts on d.c. and a.c. machines) so "reversed" that they can be solved for winding data or similar construction constants, in terms of performance.

To go further into the actual teaching of electrical design by this method, it is suggested that the student (illustrating again by the motor field) be presented with the major dimensions of a series of frames, and several sets of laminations for each. His problem would involve the determination of horsepower and speed ratings which could be constructed in each frame; standards of performance expected from each rating would be specified, and the complete performance predicted.

Here is direct contact with the problems of determining machine constants, and the limitations of design. The process would enable not just one, but many designs to be made in a short time with the opportunity for comparing trends and effects.

Any method whereby these items are stressed in teaching design would at once place emphasis on fundamentals. It would call for a completely new approach to the subject, which so far as can be learned, has never been tried, and it immediately thins out the underbrush through which the design student has floundered in his search through the design forest.

Contribution of the Engineering Professor

It is a surprising thing that the academic world has never made a more rigorous attempt at teaching design from a number of different approaches, and has made so few modifications in design teaching methods in line with the revolutionary changes in the practice over the past twenty years. It is equally surprising that so little interest and help have come to the commercial field from the engineering colleges. Considering the wide variety and technical difficulties of some of the problems of electrical design, it would seem that here is a field in which the theoretical abilities of the engineering faculty could well be applied on spare time or

research problems. Examine the technical papers which are of value to the designer; papers dealing with more accurate methods of machine analyses, or with methods of obtaining constants to yield a desired performance characteristic. With a few outstanding exceptions they have come from engineers connected with industrial organizations.

Designing a line of standard machines, say general purpose motors, may not call for any great accuracy in design methods, since some leeway is allowed in performance characteristics. But the manufacturer of devices which require motor drive does not normally buy motors "off the shelf." He sets his own standards of performance and expects the successful bidder on his business to meet or better this performance.

It is true, however, that the designer is interested in rough checks on performance in which great accuracy is not required. No general statement can be made concerning the relative importance of accurate and less accurate analyses, beyond the readily grasped distinction that for a critical item on which the designer fears for his performance, he is willing to use highly involved analyses. For other items on which his machine will not be so hard pressed, a short rough check will suffice.

Hence side by side in the designer's bag of tricks one will find inaccurate methods of calculation and those based on the most advanced applications of higher mathematics. If one engineer can design a machine accurately to closer limits and save a few cents on construction by the use of differential equations, then differential equations will be used.

Now this gives a rather confusing picture of an occupation which apparently calls for the ability to handle much detail, combining routine design, mastery of the more complex machine analyses, and technical research. The truth is that in most design offices of any size these functions are divided. The procedure of keeping up with the designs called for, checking designs and performance, and giving attention to office routine, does not provide the best atmosphere for keeping abreast of the developments of the field nor undertaking extensive individual research. These latter functions are usually provided by design research or development engineers whose duties vary widely, but in general cover the designing of the more special machines, improving where possible the office design methods and attempting to provide answers to the technical problems presented by the design staff.

Design in the Curriculum

It is very likely that deans of engineering schools can identify their practicing alumni by two groups: (1) those who complain

that the curriculum is doing nothing to train engineers in *their* particular specialty; (2) those who say "Just teach them anything, it's all good training; *we'll* show them what's what when they come with *our* organization." Any dean or department head, conscious of the pressure already exerted on a crowded curriculum must be pleased to hear the latter remarks. (A manufacturer of anything from canned peas to engineers can sleep better if he knows his market is not too particular nor discriminating.)

With full cognizance of the extent and variety of the technical problems to be found in electrical design, it would be foolish for an engineering college to attempt to turn out a design engineer. Such specialization is unwarranted. But fundamentals—I know your passwords and fetishes, academicians—fundamentals can be taught. And they are not being taught now.*

There is a growing suspicion that the engineering professor is answering all criticisms by uttering that magic word "Fundamentals." To mix our metaphors, it is the bottomless pit into which all opponents in an argument over curricula can be thrown. And like a bottomless pit its boundaries are undefined.

Many electrical engineers in their professional work will deal largely with electrical machinery. What good does it do to claim that engineering courses stress fundamentals if graduates haven't the slightest conception of how the physical dimensions of these machines are determined, the influence of various changes on characteristics, nor the limitations on physical modifications? These would seem to be fundamental to a professional background.

At the risk of repetition we could list the following fundamental design elements:

1. Methods of calculating constants from physical dimensions. These constants would cover such variety as heat dissipation coefficients of field coils to leakage reactance of distributed windings.

Where is the recent graduate who has the slightest conception of such items as the calculation of a magnetizing reactance, or who can handle adequately a problem involving irregular magnetic circuits? (And yet the academic presentation of the technique for obtaining significant machine constants from *tests,* is uniformly good. The other half of the job is the obtaining of significant constants from a *design sheet.*)

2. Adequate understanding of the reversal of the usual process of obtaining performance from constants. This point has been brought out during the previous discussion and is illustrated further by some of the designer's problems given in the appendix.

* If you insist, I will confess that circuit and machinery courses are fundamental to design, but in about the same sense that digital addition is fundamental to algebra.

3. More adequate appreciation of electrical devices as possessing mechanical and thermal, as well as electrical and magnetic properties.

It would seem, then, that the engineering professor, if he cares to act upon the following suggestions, could be of real service to one branch of the electrical field.

1. Examine the commercial practice of electrical design from the viewpoint of making personal contributions to the theory and technique involved.

2. Re-examine the possibilities of electrical design as an important part of fundamental training.

3. Evolve a new approach to the problem of teaching design in light of modern design practice.

In the meantime the electrical design offices will have to keep on hiring your run-of-the-mine engineers, still looking for that "born designer" you tell us about. "Born designer" with a mind as unsullied with the fundamentals of his work as it was on the day on which his birth took place!

Appendix

A list of problems in which the motor design engineer is interested is given below. This list makes no attempt at completeness, and it should not be assumed that the writer had any belief that these or similar problems should be covered in any undergraduate design course.

1. Methods of calculating the performance of the shaded pole motor. The reverse process of designing for a prescribed starting torque or maximum torque.

2. Simplified method of determining the important characteristics of the capacitor motor. An expression for the maximum torque of such a motor (running with condenser) so that its windings can be fixed to yield a required value of maximum torque.

3. Methods of designing the unexcited synchronous motor with processes for calculating the maximum or pull-out torque when the high reluctance area between the poles takes on various shapes. Expression for the pull-in torque of such machines or criteria whereby their ability to synchronize can be measured.

4. Design methods for the excited synchronous motor which will enable a machine to be designed with a desired maximum torque, or a fixed full-load torque angle.

5. The effect of commutation and saturation on the running performance of small series (Universal) and repulsion motors. No adequate method has as yet been devised for designing small universal motors without some element of trial and error.

6. Accurate methods for the calculation of the starting torque of repulsion motors with commutation effects considered. A reversed process whereby designs can be made to yield a prescribed starting torque.

7. Calculation of the total leakage reactance of small squirrel cage motors with concentrated stator windings. The effect of rotor bar skew has never been rigorously analyzed.

8. Further study on the heating and temperature rise of small motors, analyzed in a practical, and not too cumbersome, manner. The prediction of effects of rotor fans and duct shapes on adequacy of ventilation. Although used almost universally, the effectiveness of such cooling on small motors, is at present a trial and error process.

9. Adequate study of the temperature rise of enclosed motors, considering internal masses, fans and outer surface condition. No published method has been found to be sufficiently reliable.

10. Practical methods of determining the starting time (with specified inertia loads) of all types of motors and the losses and temperature rise during this period.

Written Discussion

By P. L. ALGER

General Electric Co.

I have read with great interest Mr. Lloyd's paper, and I sympathize with much that he says. Being myself a designer, and having been closely associated for many years with young men who are in design work, I have thought a good deal about these problems of finding men who will be good designers and teaching them the designing art. There are 3 essential steps in design work, as I see it:

First, the designer should have a thorough knowledge of the properties of materials and good judgment in selecting the right materials for use in each part of his design.

Second, he should have ingenuity, judgment, and a fine sense of proportion in devising an assembly and selecting the sizes and shapes of each piece to fulfill its required function.

And, thirdly, he should have the ability to predict characteristics and overall performance that will be obtained from any given assemblage of specified materials.

All of these functions must be carried out in every sort of design, whether it is a mechanical, an electrical, a civil, or other kind of engineering job. I think that colleges should not try to teach any particular sort of design, but rather should show their students how

to perform these various types of design work, using for illustration samples chosen from the particular field in which the student is interested, or for which he has experimental facilities.

There is presumably not much argument about giving the student a knowledge of materials, as this need not be gone into extensively; nor does it require any great amount of theory, so far as engineering students are concerned. The courses in chemistry, physics, and metallurgy afford opportunity for intensive study to those who are interested, and beyond this each student should pick up knowledge himself without direct instruction.

The art of designing a structure or an assembly that will perform the desired purpose efficiently with the least weight and cost must come largely from experience. Those who have handled metals, using machine tools, and built models of various sorts acquire an intuitive sense of proportion or judgment as to the appropriate size and shape of each piece, just as an artist acquires skill in painting. The college can, however, give the student an understanding of the laws of mechanics, of stress distribution, and other physical phenomena, which will enable him to calculate the performance of simple structures and greatly facilitate his acquisition of design knowledge.

From the point of view of college instruction, therefore, I think the basic objective is to teach the student how to predict the characteristics of a given structure. If he can calculate the torque or power factor of a given motor, then the problem of determining the motor size for a given power factor or torque is just a matter of ingenuity, which can be gained by experience in industry. What rule of thumb designers lack, and what colleges can give their students, is the ability to calculate the performance of a motor or any other structure from simple physical laws. The laws of fluid flow should be taught, and their application to problems in the flow of heat, of liquids, and of electric or magnetic flux should be explained. The student should be taught flux plotting, to enable him to determine graphically the distribution of lines of force or stress; and every means should be sought to make the laws of conservation of energy and other physical principles clear and explicit. Mathematics should be taught to designers simply as an abstract way of describing physical phenomena, so that the translation from the apparatus to the mathematics and back again can be made without effort.

If the teacher's effort is concentrated on these objectives of enabling the student to describe physical occurrences in numerical terms, and to express the relative motions of mechanical apparatus, or the current and voltage variations of electrical apparatus, in the form of simple equations, I think the best training for a designer

will be secured. Circuit theory, dimensional theory, and other ways of representing phenomena in abstract terms should be stressed, while every effort should be made to show the universal application of basic physical laws, through analogies between electric, mechanical, hydraulic, and thermal phenomena. By doing as much laboratory work as possible, experimenting with equipment, building structures, and handling materials, the student can initiate his design experience while still at college, but I do not believe that it is profitable to give any formal design courses that require detailed designing or dimensioning of complete machines.

By R. W. SORENSEN

California Institute of Technology

The teaching of electrical engineering in these days presents many difficult problems regarding what courses to include in the curriculum. In general I think experience shows that for college groups as a whole the greater service is rendered by spending as much time as possible during a student's course in the teaching of basic technical fundamentals rather than in the teaching of special phases of electrical engineering. On the other hand, for many teachers certain special engineering subjects provide a channel for the best type of teaching, because of course one can teach best the particular things which experience has made a part of the very life of that individual. Naturally, an individual who has learned the value of his own particular teaching through his own life-work channels feels very enthusiastic about that work and its value as a means of training electrical engineers. Such is to some extent the trend of Mr. Lloyd's paper, which smacks somewhat of an edict that all engineering curricula should include some rather rigorous courses in design.

For my part, I am quite willing to agree, provided the scope of the courses is quite limited and the teaching is done by someone who has had practical design experience. In this connection, I recall quite distinctly that some years ago a member of S. P. E. E. advocated the inclusion in all our college courses of a course in illuminating engineering. If every electrical engineering faculty had as a member a good teacher so thoroughly skilled in the field of illumination as was this advocate, I would agree to having such a course in all electrical engineering curricula. By the same token, if every engineering faculty had a designer with the skill and experience of T. C. Lloyd as a member of the faculty, I would think there was something amiss if the curriculum of that college did not include a course in the design of electrical machinery.

In the electrical engineering curriculum for which I am largely responsible there has always been a course in design. During recent years, however, that course has been given to fifth year students only, because of the expansion of the humanities and general education in the undergraduate course and the requirement of time for the study of basic fundamentals of electronics circuits has made it necessary for these things to be given a place in the undergraduate curriculum with the necessary postponement of some special courses like design of electrical machinery and transmission line calculations, dielectrics, etc.

As I think back over the results of approximately thirty years of teaching, during which time about five hundred students have left my teaching to go into electrical engineering, I can think of about twenty-five, or 5 per cent, who are engaged in the design of electrical apparatus. About half of these are with smaller companies and I am happy to say have achieved outstanding success in design work with these companies and are directing the design operations thereof. This group of men to my certain knowledge have never had any training in design other than that which they obtained in our design courses and which they themselves worked up without supervision of experienced designers subsequent to their graduation. I assume, therefore, that the design course given these men in college was adequate as an introduction to a successful independent career as electrical designer. The number of men who have gone into the design field and succeeded in this way is approximately equal to the number who have gone into transmission line calculations, teaching, research work, or any of the other subclassifications open to electrical engineers.

For the most part, the design course to which I refer has been a one term course taught by having the students take a standard design sheet, such as used by most any of our factories, select two or three types of machines to be designed, and under supervision calculate the design for a machine just as would be done if these men were working in the design office of some manufacturing company. No drawing or detailed mechanically dimensioned design has ever been required in this work, it being assumed that students learn the basis of drawing and machine design in other courses. In a few cases men have become particularly interested in further design work and have had some work of a research nature along the lines indicated in a book entitled, "Fundamentals of Electrical Design," by Professor Moore.

The outstanding product of this procedure was a thesis entitled, "Correlation of Induction Motor Design Factors," prepared by Vaino Hoover in 1931, and presented under that same heading at the Pacific Coast Convention of the A. I. E. E. at Lake Tahoe,

California, August 25–28, 1931. That paper, to my knowledge, has been used a number of times by young engineers as a means of constructing a design system which they could use as engineers with small companies in the development of a system of design. Unfortunately, that paper came out during a time when the A. I. E. E. could not afford to print in the Transactions all papers presented at A. I. E. E. meetings, hence that paper can be secured only by writing the Institute for a copy produced by the offset printing method. On this account the paper is not well known but is indexed and can be secured by persons interested in design.

There is much more I would like to say about certain parts of Mr. Lloyd's paper, but should I expand what I have said I feel my discussion would be another paper on the same subject, which has been so ably presented by Mr. Lloyd.

May I therefore in conclusion repeat the idea with which I started and say that when there is on an electrical engineering staff a designer with practical experience who through the teaching of design can present to students basic and fundamental ideas in electrical engineering, I think there is no better way for those ideas to be presented. But when a design course, so-called, becomes a course of tedious calculations or, worse, becomes a course largely devoted to teaching good drafting, the result will not be students who can produce original designs, but rather will be a group of men somewhat skilled in design drafting.

In other words, my comment regarding the inclusion of design in all electrical engineering courses is similar to the comment I made regarding the teaching of illuminating engineering in all electrical engineering courses; namely, any particular phase of electrical engineering can be a most excellent channel for the teaching of the basic principles of electrical engineering, and, what is equally important, the method of applying these principles to a particular task. To do this well, however, the teacher using this means must have had practical experience in the field taught as well as a thorough knowledge of the theory pertaining to the subject.

By A. NAETER

Oklahoma A. & M. College

I find Professor Lloyd's paper both interesting and challenging. I wish that it might be possible for Dr. Oboukhoff, who teaches our design work, to be present to discuss this paper. He is doing much work in carrying the method of teaching design into the third stage that Mr. Lloyd discusses so thoroughly in his paper. I am taking the liberty of sending you two copies of a recent bulletin

which outlines some phases of the developmental work that he is carrying on.

Dr. Oboukhoff is also doing much in developing methods of designing medium and high frequency inductor type of alternating current generators. He has published a series of experiment station bulletins dealing with this phase of his research work.

I have mentioned these two phases of research work that are being carried on here in a College that is far removed from the industrial areas of the North and East. As a result of the stimulation of this research, over a third of our graduating electrical engineering students choose their electives in design, even though they know that there are very few possibilities for getting into that type of work here in the Southwest. Those who have gone to the major manufacturing companies have found that their training here fits into the design program followed by them. I am merely mentioning these points to show that it is possible for college teachers to instruct their students effectually so that they are ready to undertake more serious work in design than they could without some preliminary training.

We have been able to stimulate this interest in spite of the fact that over a 10-year period, nearly 40 per cent of our electrical engineering graduates enter some phase of electrical work in the oil industry here in the Southwest. In fact, so many of them do this that it seems desirable to suggest the serious study of geology for an elective to supplement the electrical engineering training.

Oral Discussion

A. A. Nims, Newark College of Engineering, questioned why design teaching should be restricted to motors in the power field. Since the main object of teaching design is to familiarize the student with the conversion of the mathematics of the theory to actual physical relations such as sizes, materials and so forth of practice, it would seem that it would be just as desirable to design transformers, etc. The main object, after all, of teaching design is to make the principles clear to the student and to give him a feeling for sizes and rates.

F. H. Pumphrey, of Rutgers University, deplored design courses. He contended that in a four year curriculum it is impossible to include design courses and at the same time preserve the breadth of the engineering curriculum. He agreed that some design features might well be included in non-design courses.

S. P. Sashoff, University of Florida, felt that design is the best way of teaching fundamentals. He also agreed with Professor Gray that it was a considerable improvement if the object designed

could be built and tested by the student. He suggested electric circuits as a cheap and convenient field of design work.

W. G. Dow, University of Michigan, urged that the emphasis in design courses should be properly placed on thermal limitations thus stressing the factors which largely cause modification of theoretical calculations. He disagreed with Professor Sashoff in feeling that circuit design was not a proper substitute for design problems having to do with material and geometry of electrical apparatus.

D. L. Curtner, Purdue University, objected to Mr. Lloyd's suggestion of the use of standard parts in design courses. He felt that the student would want to know who worked out the standard parts and on what basis, that design courses should start from the physical laws as a basis and should avoid empirical short cuts in developing methods of attack. That the main benefit of a design course was that it required the simultaneous solution of several component problems.

J. L. Beaver, Lehigh University, pointed out that from their experience with an elective course in design, about one third of the students would elect it. He felt that standardization had no part in teaching design, that the instructor should so guide the student so that he would get it right on the second trial at the most. He disagreed with Professor Dow by urging that small machines should be used as design problems so as to avoid problems of insulation and heat flow.

G. B. Hoadley, Massachusetts Institute of Technology, urged that design should be taught as a part of all courses and that the teaching of design should be started simultaneously with the teaching of Ohm's Law.

L. A. Doggett, Pennsylvania State College, questioned the necessity of teaching of design courses at all. He pointed out that there are plently of opportunities for analysis, synthesis and judgment in the studying of the anatomy of electrical devices.

J. H. Kuhlman, University of Minnesota, objected to the use of standard parts on the basis that the students would not know from whence they come. He suggested the acquiring of small junked single-phase motors and requiring the student to build an experimental motor, using the frame and as much of the rest of the single-phase motor as possible.

M. G. Malti, Cornell University, defended the use of standard parts. He suggested that the students could be told frankly that they are not Godsent but that they are a product of experience. Their use saves time for the real problem of making the performance match with the specifications. He agreed with Professor Lloyd's ideas for a course.

Robin Beach, Polytechnic Institute of Brooklyn, wanted to know how it was possible to teach all the desirable design courses in the time allotted. He point out that only about 35 semester credits are available for electrical courses in a four year curriculum and that if the fundamentals were thoroughly taught there would be no time left for specialized design courses, particularly if both power and electronic design were to be covered. He also suggested that some of the elements of design must be given to the student willynilly in other courses.

E. W. Winkler, North Carolina State College, suggested that applications should be taught rather than design. He further suggested that specific problems in industry, where obtainable, should be substituted for regular laboratory courses.

Mr. Lloyd in rebuttal suggested that some of the professors were too frightened of the idea of using standard parts. He demonstrated that standard parts were not too restrictive or too mysterious, they were useful merely to prevent the student from thrashing around wildly. As urged in his paper, he felt that proper design springs directly from theory. It is necessary only to twist the equations to show synthesis instead of analysis.

DESIGN AND CONSTRUCTION OF EXPERIMENTAL VACUUM TUBES IN ENGINEERING SCHOOL LABORATORIES *

By TRUMAN S. GRAY

Assistant Professor of Electrical Engineering, Massachusetts Institute of Technology

The purpose of this paper is to present some of the reasons for including work on the design and construction of experimental vacuum tubes in the undergraduate course in electrical-engineering school laboratories, and to describe the way in which these ideas are carried out in the curriculum at the Massachusetts Institute of Technology.

The laboratory method of instruction, essentially an American institution, has recognized advantage over purely theoretical classroom instruction in engineering education. Among others it accomplishes the triple purpose of first emphasizing and crystallizing in the minds of the student the theoretical considerations of the classroom; second, presenting the experimental attack on problems not readily solvable by analytical methods, and third, bringing together in a study of a single device the different engineering aspects, thus showing the orders of magnitude, and the relationships and discrepancies among the principles involved.

In the early days of electrical engineering, the forms and types of machinery were not standardized, and exact design methods were not fully developed. A few approximate guides were available for design, and there were many unexplored possibilities of construction. In the educational laboratories the students not only studied existing types, but designed and occasionally constructed new or modified old electrical machines. In recent years the methods of machine design have become more fully developed. Strikingly new applications of new fundamental phenomena in machines are relatively rare now. Performance tests for many types of machines have been standardized and test codes adopted. As a result, educational laboratory methods in machine theory instruction have evolved to one of determining the performance of commercially designed devices under normal or abnormal external conditions.

* Presented at the 47th Annual Meeting, S. P. E. E. (Electrical Engineering), Pennsylvania State College, June 19–23, 1939.

In the field of electronics, which is defined † as "that branch of science and technology which relates to the conduction of electricity through gases or in vacuo," the application of newly discovered fundamental processes is still in active progress. New phenomena are being discovered, and new uses for the old phenomena are being developed continually. For example, the development of electron tubes for use in ultra-high-frequency communications has been accompanied in the last few years by intensive work on the design of magnetron oscillator tubes and Barkhausen oscillator tubes. More recently the realization of the effects of transit time, and the radically new use of velocity modulated beams have disclosed additional possibilities. In contrast to other electrical engineering fields, one cannot say that in the field of electronics the state of the art is such that performance study on commercially designed and constructed equipment is the one basic thing to be done in the educational electronics laboratory.

Design methods for those electronic devices that have become somewhat standardized, such as high-vacuum tubes, have been extended rapidly in the last decade. However, the structure, electric fields, and internal phenomena are so complicated that relatively few complete and accurate theoretical relationships that apply to them are available. An understanding of the complex relationships and the limitations of theoretical considerations is best gained by the design, construction and study of the performance of electronic equipment.

The foregoing discussion has given reasons for including a few of the fundamentals of electron-tube design in the electrical engineering curriculum. On the basis of these, the primary objectives of its inclusion is to offer to the student the opportunity to try in practice some of the fundamental theoretical principles of electron tubes, and to determine in an experimentally constructed device the limitations of and interrelations among the principles.

As stated previously, the internal action of an electron tube and the physical phenomena that underly its action and limitations are extremely varied and complex. As in all electrical equipment, the electrical aspects are often not the limiting ones. Chemical, thermal, mechanical, and physical phenomena usually govern the ratings of such devices. It is not possible to teach all of these aspects and bring out the relationships among them in the allotted classroom time. Neither are they fully appreciated under a laboratory method that attempts to emphasize them by measurements on a device of which the dimensions and materials are obtained from the manufacturer. Such a method is likely to result in a cut-and-

† Proposed definition, American Institute of Electrical Engineers.

dried series of measurements and long computations in support of the results. On the other hand, a method that involves merely analytical or graphical methods of performance prediction in a drafting-room design course without an opportunity for trial of the results by experiment is also incomplete.

The behavior of an electronic device, as contrasted with that of a device involving only metallic and magnetic conduction, is particularly difficult for a student to understand because it involves chemical, thermal, and other physical questions unlike those in anything with which he is familiar. As a consequence he is likely to stand somewhat in awe of a vacuum tube, and regard it as an unalterable mysterious device having fixed characteristics, use, and ratings set by the manufacturer. However, if he is given an opportunity to make a vacuum tube these ideas are dispelled. A confidence and breadth of view are obtained which enable him to recognize it as a flexible device of wide possibilities both of construction and utilization. In our experience, the thing that lends zest to the subject of electronics, stirs the imagination of the student, and results in enthusiastic effort is the opportunity to carry through the whole process of design, construction, and experimental study, and thereby to see the results in practice. For those schools having the objective of training engineers for pioneer work in new branches of the electronics field, such a laboratory method seems desirable and justified.

The educational method outlined above is followed in the laboratory for tube construction at the Massachusetts Institute of Technology. The laboratory is used in both undergraduate and graduate instruction, but no formal subject in it is offered graduate students. Their use of it is primarily as a tool of research, and it widens the scope of the thesis investigations that may be performed by them.

Undergraduate laboratory instruction on engineering electronics is given to students in their junior year in a subject covering the internal phenomena of electron devices and their circuit applications. This subject is organized on a conference-project basis whereby the student chooses a project in consultation with his instructor, and devotes sufficient laboratory time to the project to investigate the problem rather thoroughly. Each pair of students spends several hours in conference with their instructor and an equal number of afternoons in the laboratory. In this way, from four to six projects may be investigated during the semester. Of these, only one is ordinarily permitted on electron tube design, construction, and study, for it is recognized that the major part of the work should be devoted to the circuit application studies.

The student's background for laboratory work consists of a

classroom subject covering the theories of internal phenomena such as thermionic emission, space-charge current limitation, grid control of space current, gaseous plasma characteristics, and other related topics, followed by the principles of the circuit behavior of electronic devices. No formal directions for laboratory work are supplied, but suggestions regarding the scope of the project, and references covering vacuum technique, outgassing methods, and other constructional matters are given. These suggestions are included in the appendix at the end of this paper.

After study of this material the student brings, for approval by his instructor at the conference, plans for carrying out an experiment, together with preliminary computations on the performance of the tube to be built. In a typical case this is a simple cylindrical-plate axial-tungsten-filament high-vacuum diode. The preliminary computations for this project would include estimates of the degree of vacuum required for negligible ionization, plate current as a function of plate voltage, saturation current as a function of filament temperature, and filament temperature as a function of heating current.

One or two afternoons only are spent in the tube construction laboratory. There the stems, bulbs, and metal parts are available, and the tube assembly is readily made using electric spot-welders. After assembly the bulb is sealed around the parts in a glass-working machine in which the student observes the process and must exert some control over it for successful results. The evacuation, baking, outgassing, and getter evaporation are carried out on a vacuum system. When they are completed the tube is sealed off and based. The laboratory is open at all times during regular academic hours for further work by the student on tubes of his own design, but such work is not part of the subject. Such voluntary use together with experimental work by graduate students makes the load factor on the equipment large enough to justify the necessary investment.

Electrical measurements on the tube are made in an adjoining laboratory, and they include a study of the filament temperature as a function of heating current by means of an optical pyrometer, and measurement of the plate current as functions of filament temperature and plate voltage.

In the report on the project written by the student, a comparison is made of the experimentally determined characteristics with those predicted in the preliminary computations. Ratings of the tube are specified on the basis of thermionic emission, plate heating, and insulation.

Following this experiment further work is carried out on electron tube applications as circuit elements, but the first project

on the study of tube performance forms a basis for an understanding of tube limitations in all the subsequent work.

It must not be construed from this description that it is considered desirable to offer instruction in vacuum tube design and construction as a foundation for that as a vocation. It is admittedly impracticable and undesirable for educational institutions to keep pace with the rapid advances and improvements by industry in the development of new methods of design, new materials, and new equipment for the production of vacuum tubes. Vacuum tube design and construction for that purpose is not an appropriate subject for an educational institution, just as indicating instrument design and construction, for example, is not appropriate. However, the program outlined previously does not conflict with this point of view. Care is taken to point out to the student that the methods of construction are not those of industrial production but are the technique of the experimental laboratory. The work in vacuum tube design and construction is introduced in a subject in experimental engineering electronics as a means of emphasizing some of the fundamental aspects and limitations of electron tube behavior.

In conclusion, then, it may be said that the laboratory method is the only adequate one for instruction in the complicated phenomena of electron-tube performance. A few hours spent on the design, construction, and performance study of a simple vacuum tube is a desirable means of developing the student's imagination and his knowledge of the fundamental chemical, mechanical, thermal, and electrical phenomena that are intimately related in that rapidly developing device.

Appendix

Suggestions furnished the student concerning a laboratory project on: *Construction of Vacuum Tubes and Measurement of Their Characteristics.*

Construction.—The details of construction and exhaust of the tube will be demonstrated by the instructor in the laboratory. Before entering the laboratory the student should familiarize himself with the principles of operation of the following pieces of equipment: (1) Mechanical oil vacuum pump, (2) Oil and mercury types of diffusion pump, (3) Condensing trap, (4) McLeod gauge, (5) Thermocouple gauge. He should also become familiar with the degree of vacuum necessary in different types of vacuum tubes, with the different units in common use for its measurement, and with the effect of aging on tungsten filaments. The following references will be of aid:

1. E. E. Staff, "Notes on Engineering Electronics," M. I. T., Chap. 14 gives a summary of the kinetic theory of gases.

2. See (1) above, Chap. 15, for the breakdown of air at low pressures.
3. See (1) above, Chap. 11, for methods for the production and measurement of vacuum.
4. Forsyth and Worthing, "Properties of Tungsten and Characteristics of Tungsten Lamps." *Astrophysical Journal*, Vol. 61, p. 146, 1925.
5. S. Dushman, "The Production and Measurement of High Vacuum." This book is also published serially in the *G. E. Review*, Vols. 23 and 24, 1920 and 1921.
6. S. Dushman, "Recent Advances in the Production and Measurement of High Vacua," *Jour. Frank. Inst.*, Vol. 211, p. 689, 1931.
7. L. Dunoyer, "Vacuum Practice," G. Bell and Sons, Ltd., London, 1926.
8. Hickman, *Jour. Frank. Inst.*, Vol. 221, p. 215, 1936. Limitations of oil diffusion pumps.

Study of a Cylindrical Diode.—A diode which has a straight cylindrical tungsten cathode stretched down the center of a cylindrical anode is particularly well adapted to the study of thermionic emission from tungsten, space-charge limitation of anode current, and the effect of surface field strength on emission current.

For the study of thermionic emission [9] it will be necessary to ascertain the temperature of the filament. This can be calculated from the magnitude of the heating current and the filament dimensions,[10, 11] and if the anode is equipped with a peephole through which the filament can be seen well, its temperature can be measured by means of an optical pyrometer.[12] The Richardson relation between emission current and temperature can be manipulated so that its plot becomes a straight line.[13] If the observed values of temperature and emission current are plotted in the way suggested, the slope and intercept of the line yield values for the work function of the cathode and the coefficient of the Richardson equation. End effects resulting from the non-uniform cathode temperature should be considered.[14] One of the criteria of quality in a cathode is its emission efficiency,[15] which should be determined for various temperatures.

For the study of space-charge effects,[16] measurements of anode current as a function of plate voltage should be made, and can be plotted in such a way as to give a nearly straight line [17] whose slope yields the exponent and whose intercept yields the coefficient of Child's Law. The effect of cathode drop [18] and initial electron velocities,[19] as well as the reduced emission at the cool ends of the filament, should be considered.

Schottky evolved a theoretical relation [20] for the observed variation between thermionic emission current and field strength at the cathode surface. Measurements of emission current as a function of plate voltage in the region where the current is not limited by space charge can be plotted in such a way as to yield the coefficient of Schottky's relation. It is particularly important to have a well-aged tube for this study.

Other Projects.—A comparison of the performance of the practical types of cathodes may be made using tubes of similar dimensions. The preparation and activation of thoriated-tungsten and oxide-coated cathodes is discussed in Appendices of Chapter VIII of the text. The emission efficiency of the cathodes at their normal operating temperature is of particular engineering importance. It may be studied conveniently by extrapolation of data plotted on power-emission charts.

A triode using either a parallel-plane or a cylindrical structure and a tungsten or thoriated-tungsten filament may be constructed. Careful note of the dimensions should be made, and the overall static and dynamic characteristics of the tube compared with those computed [21] theoretically.

The secondary-emission properties of different plate materials and their effect upon the dynatron [22] characteristics of triodes may be studied conveniently using tubes of similar dimensions. Iron, nickel and carbonized nickel are suitable materials.

After the development of some skill in glass fabrication, the student may attempt the construction and measurement of the characteristics of other tubes such as a simple magnesium-cathode phototube, a glow discharge tube, or a gas-filled relay tube.

9. S. Dushman, "Thermionic Emission," *Reviews of Modern Physics*, Vol. 2, pp. 381–397, 1930. A review of the essentials of the subject.
10. E. E. Staff, "Notes on Engineering Electronics," Chap. 21, or
11. *G. E. Review*, Vol. 30, pp. 310–319, 354–361, 408–412, 1927, for the paper entitled "Characteristics of Tungsten Filaments as Functions of Temperature," by Jones and Langmuir.
12. See (10) above, Chap. 10. "Theory and Use of the Optical Pyrometer."
13. Chaffee, "Theory of Thermionic Vacuum Tubes," p. 61, McGraw-Hill Co., N. Y., 1933.
14. See (9) above, p. 390, or (10), p. 12 of Chap. 21, or (11), p. 356.
15. See (13) above, p. 122.
16. See (13) above, p. 72, et seq.
17. See (13) above, p. 74.
18. Van der Bijl, "Thermionic Vacuum Tube," p. 64, McGraw-Hill Co., N. Y., 1920.
19. See (13) above, p. 75.
20. See (13) above, p. 86, et seq.
21. Kusunose, "Calculations on Vacuum Tubes and the Design of Triodes," *Researches of the Electrotechnical Laboratory*, No. 237, Tokyo, Japan, 1928 (in English).
22. Koller, "Physics of Electron Tubes," pp. 65–73, McGraw-Hill Co., 1937.

Discussion

George D. O'Neill, of Hygrade Sylvania, Salem, Mass.: I particularly agree with next to last paragraph.

Proper preparation for tube engineering is, in my opinion, more chemistry, more physics and particularly more mathematics.

With adequate preparation in the fundamentals, the practical aspects of design and manufacturing practice are easily mastered, while a laboratory course might absorb time which might be spent with greater profit on the basic principles.

However, in discussing tube problems with engineers working on tube applications, the fact is outstanding that they are often badly handicapped by lack of sufficient knowledge of what Professor Gray calls "the fundamental aspects and limitations of tube behavior." As an example, few circuit engineers appear to realize that even in a simple class A triode, with a given set of test conditions, a tube can be designed for only one value of transconductance and plate resistance when the amplification factor and plate current have been decided upon. Such phenomena as grid emission, the spasmodic discharge of stray electrons from the glass walls of the tube, and other phenomena are frequently overlooked with more or less disastrous results. They are the people who could profit greatly by the course described by Professor Gray.

Recognizing the facts that it is impossible for the engineering student to predict exactly what knowledge he will eventually need and that the applications of electronic devices are becoming so widely extended, it would seem to me that a laboratory course which includes the design and actual construction and testing of tubes will in the near future be as essential in the training of all electrical engineers, or at least those specializing in communication, as almost any other study in the curriculum.

O. K. Marti, Allis-Chalmers Manufacturing Company: Professor Gray is quite right that the electronic devices of today have not reached the perfection in design as have the apparatus and machines of other branches of electrical engineering. It is therefore very important that engineering colleges provide an opportunity for the student to actually test a vacuum tube which they have assembled themselves. This is the case especially since the use of electronic power equipment in recent years has expanded very rapidly and is employed in all fields of power application. This will create an ever increasing demand for well trained electronic engineers.

Many universities and educational institutions throughout the country are fully aware of this. However, I would like to emphasize the fact that it is necessary to furnish the engineers of today and of the future not only with a knowledge of the use of tubes and tube circuits, but also with a knowledge which will enable them to improve the design of vacuum tubes, and to create new types. Whereas the basic characteristics of electronic devices can be studied with small tubes, the important problems of designing anodes and grids, as well as the processes of evacuation, de-

gassing, cooling, sealing, etc., cannot be studied easily with these tubes, and these problems are of the utmost importance in the training of competent design engineers today.

Such studies can, however, only be made on a tube which permits the building-in of different anodes and grids as well as indicating devices for measuring temperature, mercury vapor pressure and ionization at different locations in the interior of the vacuum tube. Our company, as some of you know, has for this very reason, and also to encourage research projects in university laboratories, built a small metal tank mercury arc electronic tube embodying all of the characteristics of modern commercial equipment.

Considering that there is already an installed capacity of pool-type rectifiers of some 4,000,000 kw., with current ratings up to 6000 amperes, and voltage ratings up to 22,000 V. d-c., per tube, it should be realized that the rectifier of the mercury pool cathode type is going to stay and that it will play a more important part in the industry where large amounts of d-c. are required. In fact, only recently three installations of pool-type rectifiers with d-c. capacities of nearly 30,000 kw. each were put into operation.

Knox McIlwain, Moore School of Electrical Engineering, Univ. of Pennsylvania: When I was first asked to discuss Professor Gray's paper on the design and construction of vacuum tubes by undergraduate students my immediate reaction was "what a lovely dog fight that will be." For I believe that the most commendable recent trend in engineering education, and one in which Professor Gray's Institute has played an important part, is to incline the student more to the professional point of view than to the artisan's. The decline in the amount of shop work, drawing, and design courses, and the corresponding increased time devoted to broadening and humanistic studies all bear witness to this fact.

However a careful reading of Professor Gray's paper relieved many of my fears, in fact left many of my arguments stillborn. For Professor Gray himself insists that "It must not be construed that it is considered desirable to offer instruction in vacuum tube design and construction as a foundation for that as a vocation." Aud further that "Vacuum tube design and construction for that purpose is not an appropriate subject for an educational institution." With these sentiments I heartily concur.

What then is to be gained by the design and construction of a single experimental tube—for each student is expressly limited to one. Professor Gray lists: emphasizing the theoretical considerations of the classroom, development of the experimental attack on problems not susceptible to analytic methods, and third giving a feeling for orders of magnitude and the importance of the approxi-

mations involved in the theory. That these ends will be forwarded somewhat by a design and construction project seems unarguable. Certainly four or five afternoons would seem well spent to accomplish these objectives.

What argument is there then left against the valuable practice advocated by Professor Gray. Simply that of *time* and the *relative* value of various ways of spending it. Practically every paper we read screams "Stress fundamentals in school and leave design and application to industry." And if the student is to design and construct a vacuum tube, why not a relay, either mechanical or electronic, or a new fluorescent lamp, or an audio frequency transformer, or a barrier photocell, or a deion circuit breaker, or a fancy wave-filter, to mention only a few of the devices which are largely in the developmental stage. Professor Gray says that "the thing that lends zest to the subject of electronics, stirs the imagination of the student, and results in enthusiastic effort is the opportunity to carry through the whole process of design, construction, and experimental study." If this is an advantage in one new field—why not in all. And I think we must recognize that it would be an advantage in any field.

Thus we are faced with a trilemma:

1. Either the method doesn't have any great effect on the student, in which case the four or five afternoons are of dubious value, or

2. The method works so well that an excess of interest will be roused for the electronics work at the expense of other courses, or

3. In order to keep a balance of interest, weeks of time must be spent to design, construct, and test, the many new devices and gadgets that are now in a developmental stage, preferably at least one for each subject which the student studies.

The solution of this trilemma I leave in your hands.

ELECTRICAL ENGINEERING COURSES FOR MECHANICAL ENGINEERING STUDENTS*

By L. E. BECK

Associate Professor of Electrical Engineering, Purdue University

In the analysis to which engineering education has been subjected, particularly during the recent years of economic stress, increasing attention has been given to the technical courses taken by the student in departments other than that administering his major work. While these discussions have tended toward quantitative analyses involving the number of credits of such courses required in a given curriculum, there has also been considerable attention given to the aims of such courses in general and to their relationship to the curriculum as a whole. In the final analysis, however, the place of a given course in a specific curriculum is determined largely by the content and nature of that course itself. This topic is difficult to deal with adequately in a general way because of the large number of courses involved and the diversified nature of these courses. It therefore seems best to limit the discussion to a single course, even though some of the statements are equally applicable to other courses in the curriculum. In this instance, the author wishes to confine his remarks to the field of his major interest at this time, namely, an electrical engineering course given to students majoring in mechanical engineering.

Probably the three major features requiring attention are the general aim of the course, the subject matter presented, and the procedures followed in its presentation. These three things are naturally interdependent.

In setting up the aims of such a course, care must be exercised to make them consistent with the general aims of the curriculum to which they belong. Furthermore, in the special case of the course in question, we must recognize the fact that the work of the mechanical engineer and that of the electrical engineer are very closely related. Dean Spencer, in his study of mechanical engineering subjects taken by electrical engineers, appearing in the S. P. E. E. JOURNAL of December, 1937, emphasizes this as follows: "In the field of electric power the electrical engineer looks to the prime mover of the mechanical engineer to drive the generator; to the

* Presented at the 47th Annual Meeting, S. P. E. E. (Electrical Engineering), Pennsylvania State College, June 19–23, 1939.

principles of machine design for the design of a large part of the generator; to the methods and machines of the mechanical engineer to manufacture a large part of the generator; and to the machines of the mechanical engineer to use a large part of the generator's output. . . . Likewise the mechanical engineer is dependent on the electrical engineer for energy to drive his machines and for the distribution of this energy to the place where it is convenient for use. The electrical engineer and the mechanical engineer must work hand in hand." Therefore care should be taken to familiarize the student with the interdependence of the subject matter of these two branches of engineering, and also to point out similarities in the analytical relationships applied in the two fields.

Two of the major teaching aims to be considered and evaluated in such a course are the teaching of technical facts, both specific and fundamental, and the training of the student mind in the application of these facts. One of the greatest difficulties is that of establishing a proper balance between these two aims. If we are to be consistent with the general trend of engineering education, however, we must place our major emphasis upon fundamental principles and analytical methods. To quote President Nash * of the University of Toledo, "No matter how much we try to cram into a boy's head in four years we cannot make him an engineer. We can give him only the foundation; if he is to rise in his profession it will be only through long years of experience and study in his special field." Professor Frank M. Smith,† in a discussion of mechanical engineering courses for electrical engineers, states; "After all, our prime objective is to help the student form habits of logical and analytical thought, and, at the same time, become familiar with fundamental principles." Obviously there are certain facts regarding electric circuits and electrical equipment which any mechanical engineering graduate should know, but if we are to take too seriously the statement of every employer regarding the shortcomings of our graduates in connection with the specialty which he manufactures, our courses will become a hodge-podge of encyclopedic information, lacking in unity, thoroughness, and in many of the features which serve to arouse and maintain student interest. It seems best, therefore, to make a very careful selection of the facts to be taught and the techniques to be learned, in the light of their general usefulness and their adaptability to analytical treatment, and to lay our major emphasis upon fundamental principles and the proper method of applying them to the solution of specific problems.

The question of the subject matter to be included is a trouble-

* S. P. E. E. JOURNAL, December, 1937, p. 308.
† S. P. E. E. JOURNAL, March, 1938, p. 481.

some one. Three difficulties stand out in connection with a course such as this. The first is the fact that the field of electrical engineering has expanded so extensively in recent years that only an exceedingly small part of it, in terms of subject matter, can be studied in such a course. The second is that the number of hours which can be allotted to such a course in the curriculum of mechanical engineering is necessarily small as compared to that allowed in the curriculum of electrical engineering to cover the same general subject. As a third limitation, we must face the fact that the analysis of many of the electrical devices, particularly those more recently developed, is relatively complex, and that an adequate treatment of them is impossible unless the student is already familiar with the special analytical methods commonly used by electrical engineers.

Regardless of the limitations mentioned, there are certain topics which in all probability would be conceded a place in such a course by general consent. Certainly the student should become familiar with the fundamental electric circuit relationships; he should be familiar with the general terms and units in common use in the profession of electrical engineering; he should be able to analyze the effect of the introduction into the circuit of new circuit elements or changes in magnitude of the elements already present; he should know the importance of the magnetic circuit in connection with electrical devices, and should understand its nature. He will, of course, be made familiar with the principles of generator and motor action, and will naturally expect to carry these principles through to their logical conclusion and learn something about the characteristics of operation of generators and motors. He should understand the nature of alternating current, both single-phase and polyphase, and be able to apply sine-wave theory to the solution of problems involving it. Naturally, it is not possible in an article such as this to enumerate all the topics which should be included, but it is safe to state that the "indispensables" are so numerous in detail that their adequate treatment requires a very large part if not all of the time normally allotted to such a course.

A casual inspection of the outline of a typical course may lead to the remark that there is too much emphasis placed on power circuits and power devices. What about communication circuits, control devices, electronic circuits and devices, special electrical instruments, and so on? The answer is that while we are studying power devices, our main emphasis is not upon these devices themselves and their operating characteristics, but rather upon the application of the electrical principles applied in their operation. They are being used as a vehicle for the teaching of the fundamental principles of electrical engineering. While it is true that

a few of these principles can be taught with equal effectiveness by referring them to some other branch of electrical engineering, communication for example, it does not appear that any other one branch can be carried through consistently with equal effectiveness and uniformity of appeal to such a large group of students whose plans for the future are very diversified.

There are at least three reasons why we prefer to use power circuits more generally than any other one type of circuit to exemplify the application of electrical principles. First, in the vast diversity of positions in which our students will finally discover their life work, there will undoubtedly be more of them who will have occasion to apply the principles of electrical engineering to power circuits than to any other one type. While we cannot expect the student to know all about any one of the branches of electrical engineering, he undoubtedly should be expected to carry away with him a knowledge of some of the facts regarding the application of electric circuits in their most common forms.

Our second reason for the predominant use of power circuits and equipment is that it lends itself readily to experimental investigation, which is such an important part of a course in electrical engineering. Suitable types of equipment are ordinarily available because of their use in the corresponding courses taken by electrical engineering students; it is sufficiently rugged to withstand most of the occasional misuse which is bound to occur when electrical equipment is handled by inexpert operators; and its operation is sufficiently self-evident to maintain the interest and enthusiasm of the students.

Perhaps the most important reason for dealing mainly with power circuits is the fact that the principles can in most cases be applied directly, so that the emphasis is upon the principles themselves and not upon the special mathematical methods required to apply them. For instance, we are able to take up most of the theory of operation of power equipment which it seems desirable that we consider without going beyond the simple vector method of analyzing sinusoidal voltages and currents. In contrast to this, we can accomplish very little in the form of rigorous analysis of communication circuits or electronic devices without taking up the special methods of dealing with circuits containing non-sinusoidal voltages and currents. To do this as a general method of approach in a course of such limited duration would have the effect of obscuring rather than clarifying the things which we wish to emphasize. This should not be taken to mean that such topics should be eliminated from the course. Certainly a student should acquire a fairly complete mental picture of the range of the field of electrical engineering. He should know the general principles of operation

and field of application of electronic devices, for instance, but if he plans to enter a field of endeavor where he will be required to analyze their operation or set up special circuits involving them, it seems best that he add, possibly as an elective subject, a specialized course dealing with these phases.

When a decision has been reached regarding the aims of the course and the subject matter to be presented, there still remains to be considered the methods to be adopted in its presentation. How may student interest be aroused and maintained? How may student initiative be encouraged? How may the diversified interests of a large number of students be coördinated in a single class? Undoubtedly the most effective answer to these and many other similar questions is the selection of an instructor who is genuinely interested in his students and the subject matter which he is teaching them. However, the adoption of certain general policies may do much to help or hinder the instructor in his work. The effectiveness of an instructor depends in no small degree upon his relations with his students as individuals, and any practice which tends to make these relations more remote is bound to be reflected in decreased effectiveness on the part of both the instructor and the student. The practice of assembling the students into very large groups to be taught by the lecture method seems to be particularly undesirable in an analytical course such as this. The problem of creating interest in electrical engineering on the part of mechanical engineering students is really not a difficult problem at all; they can very readily grasp the importance of such a course in the general program of study which they are pursuing. The problem of maintaining this interest is not quite so simple. If the role of the student is active from day to day so that he becomes a definite part of the enterprise, there is little need for artificial motivation. If his role is passive, however, as it tends to be in a large lecture room, he is very likely to find that some of the essential statements have passed by while he was gazing through the window, and that the remainder of the discussion on that topic does not quite make sense. Furthermore, the analysis in such a course is usually of a cumulative nature, so that the solution of a given problem depends upon a relationship demonstrated in its predecessor. In this event, the mind of the student whose attention has wandered is likely to divert itself toward supplying the missing details instead of following the discussion at hand, or, failing in that, to decide simply to call the whole thing off until he has an opportunity to think it all out himself that evening in the privacy of his room. This is a very laudable project for him to undertake, but with part of the information missing, he is likely to find it a very dreary enterprise, and pass on to more productive or interesting pursuits.

The alternative for this is the scheduling of students wherever possible in divisions small enough to be handled by the recitation method. This in itself does not assure success, of course, but in the hands of a reasonably skillful instructor, there will be no serious competition from external distractions. If the instructor will act chiefly in the dual role of director and interpreter, keeping always before the class some problem to be solved or question to be answered, he will find it unnecessary to resort to artificial means of stimulation. It is true that there will be suggested a large number of wrong answers which would not otherwise arise, but this business of separating the spurious from the genuine is an essential part of engineering education, and one to which the students apply themselves with great zeal.

Laboratory practice is usually considered an essential part of a course in electrical engineering for mechanical engineering students. The opportunity which it affords for the student actually to handle and test electric circuits and apparatus does more to dispel the mystery surrounding electrical phenomena in the minds of the students than any amount of classroom or demonstration work can do. If it is very closely correlated with the classroom work, it takes on added significance, and the laboratory becomes a place in which the theories of the classroom are checked by actual test. In the electrical engineering courses at Purdue University, we use a scheme of correlation which we believe gives superior results. It consists of making each course an articulated course in which the classroom and laboratory work are given as a single unit, the same instructor directing both the classroom and laboratory work for a given group of students. While this method gives rise to certain difficulties regarding the arrangement of schedules and is less economical of the time of the staff members of higher rank than would be the case if the class and laboratory work were separated, we feel satisfied that the results amply justify the inconvenience.

The advisability of administering a common course to serve both as a fundamental course for electrical engineers and as a complete course for mechanical engineers is a question which naturally arises. At Purdue we have inclined to the viewpoint that such a compromise course would not satisfy quite as well the requirements of the two groups as separate courses do. In the fundamental course for electrical engineers, we prefer to go into many topics in much greater detail than can be done for the mechanical engineers. For instance, the electricals take up the more complex magnetic circuits, they study in greater detail resistances having non-linear characteristics, and they consider more of the features of circuits which are not in the steady state condition.

Finally, it seems important that the student be familiarized with his limitations. To this end, it seems advisable that features be included in some of the problems which cannot be analyzed completely by means of the methods which are already familiar to him. The instructor can then outline briefly the methods to be applied in the proper analysis of the problem, and point out the field of study required for a mastery of the method. Care must be exercised in the assignment of such problems for homework, however, so that this feature does not overburden and therefore discourage the student. It is well to point out also, particularly at the end of the course, the large number of topics which might have been included but were necessarily omitted, and to give the students some ideas regarding the methods to be followed, either by taking special courses or by independent work, in acquiring this specialized training. In the words of the Report of the Investigation of Engineering Education, "The most serious deficiency in engineering education is not so much in matter taught or omitted in college, as in allowing the orderly process of education to stop, where it so often does, at graduation."

Discussion

G. C. Blalock, Purdue University: A major aim in teaching the principles of electrical engineering to mechanical engineering students should be, it appears to me, to give the student a thorough appreciation of the operating characteristics and limitations of electrical equipment likely to be used in conjunction with mechanical equipment designed by the mechanical engineer.

A familiar example is the machine tool, practically all sizes and types of which are nowadays designed for individual motor drive. Indeed many machine tools employ more than one motor—one or more being used as a source of driving power and others for control purposes. More and more it is becoming the practice to build the electrical equipment into the machine, making it a part of the mechanical structure. The designer of mechanical equipment should therefore understand very clearly the physical limitations as well as the electrical characteristics of the electrical equipment which is to become a part of the finished machine.

This emphasizes the need for some instruction in manufacturing standards as well as temperature limitations of electrical equipment. The student should learn something of the basic reasons for the name plate ratings of electrical equipment, the conditions under which and the extent to which electrical equipment may safely be loaded beyond its rating, the need for adequate ventilation of such equipment and something of the weight and speed limitations pertaining to more commonly used industrial electrical equipment.

The mechanical engineer is very unlikely ever to have responsibility for *design* of electrical equipment; his problem is more likely to be that of coördinating more or less standardized electrical equipment with his more or less original designs of mechanical equipment, or simply that of furnishing existent machines with electrical drives and control. This leads to the need for instruction in the determination of power requirements, speed and torque characteristics of driven machines; the data upon which to base a choice as to type and rating of motor best suited to the drive.

Every factory has examples of poor judgment in the choice of motors for machine drive—not necessarily that the motor does not supply sufficient power but that the motor may be sufficiently overloaded to cause unduly high maintenance charges, may be very much oversize—resulting in an investment loss as well as abnormal operating losses, the means of transmitting the motor power to the load may be faulty, resulting in unnecessary losses, or the operating characteristics of the motor may be unsuited to the application, resulting in loss of production under some conditions of load or in the necessity for excessive attention upon the part of the operator.

Sometimes the designer of mechanical equipment is in position to turn the problem of fitting the machine with a proper driving or control motor over to the electrical engineer and here it is likely that considerable expense might be saved if the mechanical engineer, through an understanding of the characteristics of electrical equipment, could so modify the characteristics of his machine as to permit the use of standard electrical equipment or at least prevent the necessity for use of unduly expensive special designs.

The specialized fields of power generation, transmission and distribution will not ordinarily be in the line of interest of the mechanical engineer except in a very general way. Likewise the matters of design and operation of electric generating equipment should be subordinated to a more intensive study of motor types, their operating characteristics and the various types of hand and automatic control devices availables. In connection with study of control equipment some attention should be given the thermionic devices which are being used to an increasing extent each year in connection with control of routine machine operations.

Some attention should be given the matter of industrial lighting. The mechanical engineer should be well informed as to the effects of good lighting upon accident and production records. It is true that he may, and *should,* call in an electrical expert for design or redesign of a lighting system but he should be sufficiently informed on his own account to recognize defects in the lighting plan and the need for expert service along this line.

In general, less emphasis should be placed upon basic theory

with non-electrical students and more emphasis placed upon operating characteristics and features pertinent to intelligent application of electrical equipment. The instructor should have had practical experience and direct contact with industry. Otherwise his point of view is likely to be distorted in favor of theory, with little or no emphasis upon practice. The success of the non-electrical course is likely to lie in the ability of the instructor to bring to the student a consciousness of the practical value to him of the course content.

The problem is essentially the same for students majoring in other branches of engineering than mechanical or electrical, the same course frequently being given all engineering students besides the electrical. Where possible, however, it is desirable to have the various groups taught as separate sections or divisions, in order that emphasis may be placed, with each group, upon the type of industrial application in which it is most interested.

In general, the amount of material to be covered in a course given non-electrical students is too great to be covered in one semester. At Purdue three class hours and two laboratory hours per week for two semesters are devoted to the course given mechanical and chemical engineers while three class hours and three laboratory hours per week for one semester are allotted the civil engineers. The shorter time allowed the course for civil engineering students makes this a difficult course to administer satisfactorily from the standpoint of students and instructor alike. It can be made little more than a survey course and the rapid procession of topics or types of equipment tends to confuse the student. However, it is felt that the civil engineering branch has the least need of all the branches of engineering for familiarity with electrical equipment and that this need can be satisfied by giving the student a very general idea of types and characteristics of circuits, motors and control equipment.

G. B. Hoadley, Massachusetts Institute of Technology, stressed the importance of small classes in teaching electrical engineering to mechanical engineering students. He felt this to be particularly important since these students are learning a subject somewhat removed from their main interests. He felt that about two weeks of electronics should be included in such courses.

R. W. Tapy, University of Detroit, stressed the importance of requiring proper laboratory reports from mechanical engineering students. He also urged that the courses be made as practical as possible, including such practices as presenting simple control circuit blueprints to be analyzed in class. He also felt that electronics should be included as part of the course.

C. D. Fawcett, Moore School of Electrical Engineering, Uni-

versity of Pennsylvania, polled the group to discover the number of hours usually allotted to teaching electrical engineering to non-electrical students. The results showed no institutions giving less than four semester credits of hours of class room work; 10 institutions giving four semester credits; 16 institutions giving six; three institutions giving seven; one institution giving eight and two institutions giving as much as nine semester credits of class room work. In addtion, 32 institutions gave three hours laboratory for two terms; six institutions gave two hours laboratory for two terms and one institution gave one hour laboratory for three years.

REPORT OF CONFERENCE ON ORIENTATION OF FRESHMEN

The Chairman of the Committee on Orientation of Freshmen, A. R. Cullimore, opened the conference with the statement that educators are beginning to realize that most of the causes for the failure of engineering students, and particularly underclass students, are not matters of mere dumbness—mental deficiency—but rather of physical, or emotional defects or disturbances, which conspire to bring about and then to aggravate academic or professional failure. He outlined briefly the work already done by this committee in formulating the realization of the existence of this condition and in presenting it to the Society and then stated that the committee has investigated possible remedies for these student difficulties. Techniques exist for diagnosing the troubles referred to, and remedies are available within the present structure of the educational system. To demonstrate this fact, the committee invited two outstanding men, in different but related fields, to address the conference. Joseph E. Raycroft, New Jersey State Department of Institutions and Agencies, and formerly of Princeton University, presented a paper on the subject "Factors Other Than Intellectual in the Training of our Engineers." He stated that in the past twenty years "There is an increase in the number of adolescents who are unequally developed" and that "the responsibility . . . is generally attributed to the profound changes that have taken place in family life and relationships." He further said that "more responsibility has fallen upon the school to recognize and provide for the needs in the emotional training of the child. . . . Administration of this phase of the educational experience at the college level calls for the services of competent doctors and psychiatrists and the coöperation of supervisors of extra curricular activities . . . ." Dr. Raycroft then outlined a procedure for the obtaining and coördinating of the information needed, and for using it to the benefit of the student. He closed with the words: "Experience has shown that upwards of ninety per cent of such cases can be helped gradually to attain a stable adjustment and to maintain high standards of work during a college course, but still more important to make a success of living. Surely this is a result worthy of our best efforts."

Emmett A. Betts, Department of Education and Psychology, Pennsylvania State College, spoke on "Some Experiences with

Reading Clinics." Dr. Betts presented a number of illustrations, taken from the files of his Reading Clinic, of the procedure being followed in the diagnosis of difficulties arising from poor reading-habits. In some cases a physical cause is uncovered, such as different speeds of nerve action as between the right and left eye, etc. Sometimes the trouble arises from inadequate vocabulary, or from improper arrangement of lighting in the student's study room. From the actual records referred to by Dr. Betts, surprising improvements, as indicated by term grades resulting from the correcting of the conditions revealed, have been obtained.

At the conclusion of Dr. Betts' presentation, President Cullimore commented on the subject matter of the two papers, and showed where they fit in the work of the Committee. Any recommendation by this Committee for or against consideration of the orientation of maladjusted students must be based on a study of the seriousness of the problem, the amount of effort required for attacking it, the probability of success, and the comparative value of success to the student, college, industry, and society at large.

In the three years during which the committee has functioned, two reports have been made prior to the present conference. These reports pointed out the existence of the problem of undergraduate mal-adjustment, and its serious effects on engineering education. In general the Arts Colleges had already made notable progress in the study of this problem and in the development in technique for its solution. The papers by Dr. Raycroft and Dr. Bettes, both of them men of wide experience in Arts Colleges, gave to the conference an excellent idea, not only of techniques, but also of degrees of success to be expected. These techniques appear to have possibilities in the field of engineering education; particularly if they are considered as suggesting principles to be followed, rather than rigid formulæ. They suggest, in fact, the need for flexibility so that each faculty can work out its own solutions. Broadly speaking, the basic principle might be said to be setting up habits that are (*a*) constructive to the ultimate end and (*b*) emotionally satisfactory. Among these habits are such things as the breeding of confidence, self discipline, a sense of responsibility, good manners, a professional attitude, etc.—all habits that appear to have a deferred emotional satisfaction. Immediate emotional satisfaction is sought by students in such fields as athletics, social contacts, drinking, etc. An important phase of the general principle is certainly the setting up of proper habits in these matters, as well as in those that will bring satisfaction in later years.

H. N. CUMMINGS,
Temporary Secretary

MATHEMATICS AND THE ENGINEER*

By S. G. HACKER

State College of Washington

The engineer is concerned with the hard realities of Nature. His dams must succeed in keeping back the waters. His dynamos must succeed in generating electric current. His roads and bridges must withstand the heavy toll exacted by a constantly increasing traffic, nor fall an easy prey to the onslaught of the elements. Failure is not allowed. And yet all the while there are so many vagaries of Nature, so many details important in themselves or vital only in the aggregate, ready to destroy him—so strong a field ready to induce failure in his work. He does work against this field. Nature forces him to acknowledge the second law of thermodynamics as the universal postulate of experience.

It must not be forgotten, however, when we use the word Reality that it is an elastic term encompassing only the known and the charted. Beyond lie the unknown and the unexpected. Reality is a bounded region. The future development of engineering, as of all science, will be achieved by extending these boundaries of present knowledge. What is unknown today may be an essential part of the reality of tomorrow.

These important responsibilities must be kept in mind in any discussion bearing on the improvement of engineering education. Particularly is this so in the case of mathematics for it plays a fundamental rôle in engineering science.

1

The problems of teaching mathematics in a way that will be most helpful to students of engineering are many and great. They have been frequently discussed at meetings of both engineering and mathematical societies, in this country and abroad. Indeed, so much has been said on this subject that it is difficult to add anything essentially new. The concensus of opinion has generally been that the mathematics instructor whose work is largely given over to teaching engineering students should himself know more about engineering, at least so far as regards the problems and the difficul-

* Presented at the 1939 meeting of the Pacific Northwest Section, S. P. E. E.

ties which the practicing engineer must face. The wisdom in this is apparent.

In some institutions, however, the desire for emphasis on what are supposedly engineering aspects in even the earliest mathematical instruction has been so great that separate courses in the same mathematical subjects are given to engineers and non-engineers. In still other cases this emphasis has led to the division of the mathematical faculty into two departments, one of which is concerned with the instruction of engineering students and the other which is not.

These plans have been acceded to by those mathematicians who feel as did Felix Klein, the distinguished German mathematician who was largely responsible for the improvement of mathematical instruction in Germany about fifty years ago, that "In all instruction, even in the university, mathematics should be associated with everything that is seriously interesting to the pupil at that particular stage of his development and that can in any way be brought into relation with mathematics."[1] It has therefore seemed wise to them to separate the engineers so that references to engineering applications can be freely presented.

On the other hand, there are many who feel that a student's basic mathematical education is impaired by a continually expected reference to engineering applications. They believe that there is much to be learned by the study of mathematics itself, and that when it is properly taught, the student acquires a purely *mathematical* insight which is invaluable to him in the study of the more mature aspects of whatever science in which he may be specializing. To supplement this, advanced undergraduate mathematical courses especially framed around engineering problems are often offered for capable students who can bring to the classroom a knowledge of sound engineering principles and a satisfactory mathematical background.

In the early mathematics courses, when the student's knowledge of both engineering and mathematics are still decidedly immature, the mathematical applications to engineering are not apt to be of a fundamental nature. Certainly the student does not profit from "applications" which are obviously trivial. No one will gainsay, however, the great benefits to be derived from the application of mathematics to worthwhile engineering problems.

The opinion of a first-class mathematician whose work has been largely devoted to the study of engineering problems might be profitably consulted. Dr. Thornton C. Fry, of the Technical Staff

[1] Klein, F.: "Elementary Mathematics from an Advanced Standpoint." (English Translation by Hedrick and Noble, 1932.)

of the Bell Telephone Laboratories, will be so recognized. In answer to certain inquiries of the writer, Dr. Fry once wrote: [2]

> . . . Industrial research changes its aspect so rapidly that I cannot be at all sure that a subject which I would regard as unimportant at this time may not be of the highest importance within a comparatively few years. . . .
>
> I think my advice to the student who hoped some day to find employment in the . . . engineering industries . . . would be not to worry too much about whether his courses of study all had specific applications in these industries, but rather to choose them with a view to building a broad and well-balanced foundation for the understanding of mathematics in general. In so far as specialization is consistent with this primary purpose, I would suggest that he choose his courses because of their relationship to the basic science (physics, chemistry, electrical engineering, and so forth) in which he felt the greatest interest. I believe a student who followed this advice would suffer no handicap whatever in seeking industrial employment, whereas if he chose the other plan he might possibly be handicapped if he later decided to seek some other type of employment.
>
> It follows also that I would not advise an instructor in applied mathematics to worry so much about whether his courses were practical in the industrial sense, as whether they were sound according to the best mathematical standards and fundamentals in the light of the applications which were being made of them in other fields. I do not mean, of course, that he should avoid the practical aspects of his subject. On the contrary, if he does his job well he will indicate quite clearly what they are. I merely mean that this should not be his primary purpose.

2

Let us now consider briefly something of the real *character* of mathematics. There is a mathematical *Conception,* a mathematical *Spirit,* and a mathematical *Method.* By the mathematical *Conception* I refer, for want of a better word, to the *manifold of purely mathematical ideas* of which mathematics consists. These ideas are uniquely mathematical. It was of them that Sophus Lie, the great Norwegian mathematician, was no doubt thinking when he named imagination ("Phantasie") as the first necessary attribute of a mathematician. To learn mathematics the student must comprehend these mathematical ideas and he must come to think explicitly in terms of them. This is far different from mastering a technique, which is too often confused with mathematics. It is a far different thing to be able to differentiate or integrate by some rule of thumb than it is to understand the meaning of the derivative or the definite integral, not to mention, for example, the modern theories of integration. A robot could be made which would

[2] Fry, T. C.: Personal Communication, May 1, 1936.

be able to differentiate a polynomial. If it were not so vapid a game for his quick mind a little child could do it with blocks. It is, however, another matter to comprehend the *Idea* of the derivative. Our teaching in mathematics tends too often to develop only the abilities to "follow" a set of mathematical relations in a manner which is a mechanical routine, just as too much of the instruction in the engineering sciences produces men who are not engineers but only meter-readers! Herein, I believe, lies a principal difficulty, for too many teachers of mathematics are in a way only meter-readers themselves. A person can read an ammeter or a voltmeter without any real understanding of electric and magnetic fields or their mutual interactions. So, likewise, a man can read a page of mathematical relations following them from the first to the last by mere verification without comprehension.

Too often in the mathematics classroom equations, symbols, technical vocabularies are bandied about in a lifeless fashion. This sort of instruction amounts to a sleight-of-hand performance without the advantage of even being entertaining, because after all it is supposed to be a really serious matter. These so-called mental gymnastics are supposed to develop one's mental agility. The reputed benefit of mathematics when taught in this fashion is on the contrary to be doubted. Learning vocabulary after vocabulary in a foreign language, is of very doubtful benefit if one never learns to understand an idea expressed in that language; and real success comes when one can think in terms of that language and express real ideas in it.

It must be said, of course, that mathematics has not always developed with absolute freedom from mechanical technique. Many developments have literally *forced themselves*—like the negative and the complex numbers for example—by a mechanical process. But when this has been so, these new things would be today still-born except that they have demanded and received interpretation and now have meaning. These are the developments which have arisen by a procedure which the mathematician calls algorithmic. Examples of the same sort of thing are to be found in all branches of science—like the identification of the morning with the evening star or the predicted existence of displacement currents or Dirac's conjecture of the existence of the positron. We must take our stand within the limits of the intelligible, as Eckermann said, and postulates, processes, results are meaningless unless, or until, we succeed in identifying them with intelligibility.

There is also a mathematical *Spirit*. It is characterized first by a desire for freedom from contradiction. This is the *logical* Spirit. Secondly, there is the Spirit which seeks for the unification, the

harmony of ideas. This is the Spirit of a consistent *unity*. Finally, there is the Spirit of *generalization* which seeks to "eradicate the exceptional" and to "eliminate the unessential." Some may say that this is the spirit of all science, not of mathematics alone. True science has indeed acquired these attitudes of mind and is characterized by them; but it has learned them from mathematics where they have their origin, and which has always remained the stronghold for their preservation and cultivation.

Finally, besides the mathematical Conception and the mathematical Spirit there is the mathematical *Method*.[3] It is the means by which we achieve a realization of the Conception and the Spirit. The mathematical Method, it seems to me, employs what may be called the Methods of Intuition, Generalization, and Analogy. Involved in the realization of the mathematical method from the Conception and the Spirit is the use of mathematical language—Symbolism. This language is universal, transcending all nationality and all vernacular. It is free of the pompousness and the verbosity of ordinary speech. However, the use of this language, characterized as it is by a magic conciseness, is, as we have said, too often over-emphasized to the disadvantage of those other attributes of mathematics of which we have been speaking.

It is quite clear that not always can one separate the attributes of mathematics, saying this is Conception, this is Spirit, this is Method. Sometimes it is not only not clear how to do so but to no advantage to try to do so. The Method of Intuition is too difficult to discuss here in these general terms to which we must limit ourselves but some reflection will reveal what is meant. The Method of Generalization is perhaps suggestive enough to warrant our passing it by without further elaboration. We pass from the known to the unknown by the Method of Analogy. Kepler remarked, "Above all I love analogies, my most faithful teachers, acquainted as they are with all the secrets of Nature."[3] There is a case given by E. A. Milne in his Oxford Inaugural Lecture[4] which illustrates one of the more common aspects of the Method of Analogy. In this case the method is carried along by the E. M. F. of mathematical symbolism. The same differential equation with the same boundary conditions, provided the boundary is the same in all cases, occurs in the following four problems: (1) the torsion of a rod of any cross-section; (2) the displacement under pressure of a soap-film; (3) the flow of a viscous fluid through a

[3] Young, W. H.: "The Mathematical Method and its Limitations." *Atti del Congresso Internazionale dei Matematici* (Bologna), I, 203, 1928. The discussion in the present paper follows somewhat different lines from Young's.

[4] Milne, E. A.: "The Aims of Mathematical Physics" (Inaugural Lecture), Oxford, 1929.

channel; (4) the rotation of an imcompressible fluid encased in a prism. Now Milne points out that the experimental study of (2) has facilitated the experimental study of (1), but concludes that "something of the very texture of mathematics has to be woven in before the fourfold pattern emerges."

It is this something, this texture, if you wish, of mathematics that I have been trying to bring out. Unless the student of mathematics is taught an appreciation of these things, he does not learn mathematics. Nor is it necessary to go far afield in order to point these things out to students: the study of elementary plane trigonometry starting as it does with the simple ratios of the sides of a right-angle triangle in Euclidean space, and then extending these rudimentary notions by intuition, generalization, and analogy provides an early and particularly elegant illustration. Still another is the case of exponents and logarithms. The careful study of the number system itself has a wealth of illuminating information to offer. Everywhere from the most elementary notions to the most advanced, the opportunities for examination by teacher and student abound, for this is *mathematics!* The failure to achieve the proper kind of mathematical instruction is a principal reason for much of the present discontent with mathematics. I firmly believe that if what is taught in the classroom is *really mathematics* the engineer need have no fears for its "usefulness."

3

The common distinction between "pure" and "applied" mathematics is, in a sense, a somewhat unfortunate terminology. There is only one kind of *mathematics.* What is called "applied mathematics" is simply the extension of the mathematical Conception, Spirit, and Method to the elucidation of those other fields to which men give thought and study. In fact, the extreme position is taken by Einstein [5] who, after recognizing Experience and Reason as "the two inseparable constituents of human knowledge," gives it as his assured opinion that "Our experience to date justifies us in feeling sure that in Nature is actualized the ideal of mathematical simplicity. . . . Pure mathematical construction enables us to discover the concepts and the laws connecting them which give us the key to the understanding of the phenomena of Nature. Experience can of course guide us in our choice of serviceable mathematical concepts; it cannot be the source from which they are derived; experience of course remains the sole cri-

[5] Einstein, A.: "On the Method of Theoretical Physics" (Herbert Spencer Lecture), Oxford, 1933.

terion of the serviceability of a mathematical construction for physics, but the truly creative principle resides in mathematics."

There are many however who regard Experience to be of such importance as to give to Applied Mathematics—or Mathematical Physics, or Natural Philosophy, as it is perhaps better called—a status of its own. There is a physical intuition, a physical insight, which is born and bred of contact with Reality. It is the product of Experience. Milne [4] adopts this view that Mathematical Physics is a science *sui generis*, and many will agree with it.

At least it is certainly true that mathematics has itself been immeasurably benefited by the applications to which it has been put. This influence has been of vital significance in the development of mathematics. Applied science has not only adopted the mathematical Spirit and Method for its own good but it has many times been able to make suggestions which have led to new mathematical ideas and the enhancement of the mathematical Conception. Could it be that the human mind has been so permeated and influenced by the characteristics of the environment of the physical world that in the alchemy of thought there is imparted to mathematics a natural applicability which is latent until discovered?

4

My suggestions for the improvement of the mathematical side of engineering education have taken the form of emphasizing the *character* of mathematics and how important it is that the true understanding and appreciation of it be developed in the mathematics classroom. The engineers will emphasize the rôle which experience plays. If both the engineering and mathematical instruction are maintained on the proper high level, the student has a wonderful opportunity to develop scientifically. And I may add that if there is wisdom in the suggestion that the mathematics instructor know something about engineering, it is therefore equally true that the engineering instructor should have some real understanding of mathematics.

It is most important that the whole level of mathematical instruction be raised from the grade school to the graduate school and at the earliest opportunity. Everyone knows the difficulties which such a program must face, especially in the high schools, where along many fronts, sound instruction is losing ground before the barrage of so-called modern educational theories. In the counter attack the mathematicians will need to enlist the assistance of all those who know and appreciate the value of mathematics. The engineer and his opinions are most highly regarded in every community and his whole-hearted coöperation with the mathema-

tician in forcing the proper kind of mathematical instruction in the schools is needed.

The late Justice Cardozo once said: [6]

> The theorist has a hard time to make his way in an ungrateful world. He is supposed to be indifferent to realities; yet his life is spent in the exposure of realities, which, till illuminated by his searchlight, were hidden and unknown. He is contrasted, and to his great disfavor, with the strenuous man of action, who plows or builds or navigates or trades, yet in moments of meditation he takes the consoling knowledge to his heart that the action of his favored brothers would be futile unless informed and inspired by thoughts that came from him. . . . General truths are hard to grasp. Most of us have all we can do in accumulating by dint of toil the knowledge of a few particulars.

[6] Cardozo, J. B.: "The Growth of the Law," 1924.

SECTIONS AND BRANCHES

Kentucky Section.—The fall meeting of the Kentucky Section was held at the University of Louisville on November 4, 1939, R. C. Ernst, Chairman, presiding. Dean Wilkinson welcomed the members. The theme of the meeting was What the Engineering Profession Expects of its Graduates.

Dr. Long, Chemical Engineer of Reynolds Metals Company, spoke first and emphasized two points, first, that in general the profession is not looking for the rounded man in hiring new graduates; second, that more emphasis should be placed on fundamental subjects such as mathematics, physics and chemistry, imagination, judgment and logic, memory.

Mr. Caye, Commissioner of Sewerage of Louisville, spoke, first on definite requirements for definite jobs; second, more specialization; third, training should fall into the classifications of technical, practical training, and personal attributes, such as ambition, nonantagonistic manners of speech, desire to work, neat not flashy dress, promptness in work, determination, liking for certain amount of detail work, dignity and same time a good fellow, attitude toward advancement, good draftsman and letterer.

Mr. Towner, Electrical Engineer with radio station WHAS, emphasized the following points: Solid foundation of fundamental engineering principles; love of work; loyalty and ability to coöperate; sense of responsibility; faculty advice to students on job opportunities; emphasis on work; education just beginning for graduate; prevention of waste of human ingenuity; information needed on other than own field to be obtained after graduation.

Mr. Sachs, Mechanical Engineer with Henry Vogt Company, brought out these points: Alertness, native ability, quick thinking, self confidence, personality. Criticism of present day graduates: Lack of knowledge of men in related subjects; mechanical engineer has no conception of physical chemistry; chemical engineer has not enough electrical engineering grounding; mechanical engineer needs more electrical engineering—induction heating for example; lack of feeling of responsibility.

The meeting was then thrown open for discussion and faculty, guests, speakers, and students contributed.

An attempt is to be made to arrange for a joint Kentucky-Tennessee meeting.

The Nominating Committee reported the following men for officers for 1939–40. They were elected unanimously.

C. C. Jett, University of Kentucky, Chairman.
G. H. Harding, University of Louisville, Vice-Chairman.
J. W. May, University of Kentucky, Secretary-Treasurer.

G. H. HARDING,
Sec.-Treas.

North-Midwest Section.—The North-Midwest Section held its fifth annual meeting at the State University of Iowa, October 20–21, 1939. The following officers were elected for 1939–40:

J. R. DuPriest, University of Minnesota, Chairman.
G. L. Larson, University of Wisconsin, Vice-Chairman.
L. C. Caverley, University of Minnesota, Secretary-Treasurer.

HUBER O. CROFT,
Secretary.

CIVIL ENGINEERING PAGE

Notes of interest for members of the Civil Engineering Division.
—Editor, EDWARD E. BAUER, *University of Illinois, Urbana*

M. W. FURR, *Chairman*
F. T. MAVIS, *Past Chairman*
PAUL P. RICE, *Secretary*
EDWARD E. BAUER, *Editor*
L. G. STRAUB
F. W. STUBBS, JR.
H. T. HEALD

WHAT IS EXPECTED OF A YOUNG SANITARY ENGINEER*

BY SAMUEL A. GREELEY AND PAUL HANSEN

Hydraulic and Sanitary Engineers, Chicago, Illinois

The object of this paper as explained by the Chairman of your Sanitary Section is to state, from the viewpoint of a practicing engineer, what a young sanitary engineer coming out of college should be prepared to do. Your Chairman expresses the hope that the subject matter will help teachers in engineering colleges to form a proper curriculum and to improve teaching methods. Thus the subject is directed to a description of the work of a young sanitary engineer during his first few years of practice in an engineering office such as ours.

Our practice is entirely in the field of sanitary engineering and includes investigations and reports, the preparation of detailed plans and specifications, the supervision of inspection and construction, reports on operation and rate schedules, and valuations; all in general related to water supply, water purification, sewerage, sewage disposal, flood control and similar projects in the field of sanitary and hydraulic engineering. The work required of our assistants is varied. The field of sanitary engineering is one marked by progress, and many of the assignments involve some study and research to keep abreast of current practice and particularly of operating experiences in this field.

Our requirements of a young engineer, and thus our expectations regarding his work, seem to change from time to time. During the last several years, for instance, rapidity of work and ability to produce finished results promptly have been important.

To illustrate our expectations or requirements for young engineers a few typical cases are described.

A young engineer who came to us direct from an engineering college spent the first seven months of his work in our office making construction drawings and computing quantities. These drawings were made on paper in pencil and were not traced. His job was to make these drawings from sketches and under direction and to complete them correctly and neatly so that they could become part of a finished set. Most of the time was spent on the drawings of the major structures of a large sewage treatment plant. Some of the time was spent in a small city as one of two men making similar drawings of certain sewer connections which were part of a sewage disposal project. The next five months of this young engineer's work were spent in much the same way in our main office, except for a few weeks as an assistant in the computation of alternate projects for a report on a relatively large sewage disposal project.

* Presented at the Sanitary Engineering Meeting of the Civil Engineering Division of S. P. E. E. at State College, Pennsylvania, June, 1939.

Another young engineer who came to us directly from college went to work under our Resident Engineer in the field office of a large design and construction project. He worked for a while in the field on surveys for location and then in the office on the preparation of construction drawings for intercepting sewers and made some miscellaneous computations of estimates of cost. For a short time he was in the field gathering data regarding the sewage of industries. This young engineer left after about two years of experience with us, to become a sales engineer for a large equipment company.

A third young engineer came to us after a few months of work in the office of a City Engineer of a small city. His work comprised general studies as a basis for design, rather than the production of construction drawings. During his first year he worked on the following assignments: (1) General investigations as bases of design for one large and three small sewage disposal projects; (2) a considerable amount of research and computation relating to the preparation of a schedule of charges to be made for sewage disposal service; (3) assembling data for a report on the design of sedimentation tanks for a large sewage disposal project; (4) assistance in the preparation of an application to P.W.A. for a water supply project; (5) assistance in the preparation of data for a court case involving damages on account of alleged patent infringements; (6) the preparation of general layouts and the computation of costs of alternate plans for a sewage disposal project in a small city; and (7) assisting several other assistant engineers in the last stages of the preparation of a report on a large sewage disposal project.

In addition to the foregoing kinds of work, there were several occasions on which he was assigned to assist a principal in the preparation of letter reports and similar short time work. Most of the work was under direction, but in some of it, his assignments were rather general and were directly under a principal or an experienced assistant engineer. Later, after about two years of this kind of work in our main office, this young engineer was sent out as Resident Engineer on the construction of a small sewage treatment plant.

The kinds of work expected of a young engineer, as indicated by the foregoing typical cases, may be summarized as follows: Drafting, surveying, inspection of construction, office research and computations.

Drafting does not include tracing, but requires the actual making of construction drawings from sketches.

Surveying is limited to running lines and grades for selecting routes for intercepting sewers and the like, and to the setting and resetting of lines and grades for construction.

Inspection of construction is in general, for the young engineer, part of a group under the direction of an assistant or resident engineer. Occasionally a capable young engineer will be in charge, as resident engineer, of a small project where there is close contact between the main office and the work.

A good deal of office research is required in our work. This involves a search for and tabulation of data relating, for instance, to the operation of sewage treatment plants and of water purification plants.

The great variety of the work generally tends to the use of a young engineer in the kind of work in which he is most capable. Some young engineers seem to be more adept in the preliminary work for design and others in office research and activities related to preliminary investigations or studies for the basic elements of design.

The speed, variety and interest inherent in our work make two general requirements desirable. The first of these is a lively interest in the field of sanitary engineering and in the problems and projects of our office. The second is a matter of fitness and physical condition so as to permit not only the

routine work, but also some growth by personal study, reading and inspection of allied projects, operating plants and the like. The first of these items contributes to the quality of our office work and thus enables the young engineer better to meet our expectations; and a lack of the second tends to retard our office activities. Much endurance and energy has been required, especially during the last five years, to meet the demands of a busy engineering office.

It seems to us desirable for a young engineer to have had some introduction to the field of engineering in which he proposes to work. Summer construction jobs would seem to be very helpful. Informal evening discussions led by practicing engineers at the colleges seem to offer a good method of acquainting the young engineer with engineering practice. Such discussion evenings continued at intervals for several months have proven to be popular at some of our universities in other fields of instruction.

We are not inclined to favor the allocation of much time in the college curriculum to so-called practical subjects, but inclined rather to a thorough study of fundamental subjects, such as mathematics, physics, chemistry, geology, biology, fundamentals of law and economics, and English. How best to demonstrate to the young engineer the value of slow, hard and uninteresting study in fundamentals is a problem relatively easy to state but difficult to answer. The trips arranged by some engineering colleges to visit engineering offices and structures are a helpful step in this direction. It seems likely that more direct personal contact with practicing engineers through informal evening discussions with questions and answers, and perhaps some collateral reading, is another helpful step.

There are many other general things which we like to have in a young engineer to meet our expectations. Of major importance is the ability to write good English, to understand instructions and to speak well; in short, to make good use of the English language. Another important item is the ability to present and record, clearly and neatly, the data which he has been working up. If, for instance, a tabulation can be prepared by a young engineer so that it can be used directly in a report without rearrangement, he has met one of our expectations. In making computations he must be reasonably accurate and must have a method of checking his results so that they can be relied on and used. An understanding of the end result is useful. We find that some young engineers tend to scatter their effort and not to grasp quickly and clearly the subject of the assignment.

Our impression is that all of these expectations are pretty well realized and understood by the teachers in engineering colleges. The Proceedings of your Society show this understanding very clearly. The "Qualities Needed by an Engineer," listed by Dugald C. Jackson, are far-reaching and excellent. The recommendations of the "Majority Report of your Committee on Objectives and Length of Curriculum in 1935" are stimulating and promising. You, as teachers, have a difficult task because the young students enter your colleges pretty well developed along general lines. Their physical condition, their intellectual habits and their spiritual attributes have been pretty well formed before entrance to an engineering college. Characteristics such as these, however, are important if there is to be growth and development beyond the purely technical service of a young engineer. During the past few years there has been little opportunity for teaching or apprenticeship in engineering offices. It is a tribute to the quality of engineering education that the engineers have been able to meet the pressure of depression days and that young sanitary engineers have in the main secured jobs and kept abreast of the rapidly moving current of engineering practice.

ENGINEERING ECONOMY PAGE

Engineering Economy deals with comparisons between technical alternatives in which the differences between the alternatives are expressed as far as practicable in money terms.

EDMUND D. AYRES, University of Wisconsin, *Editor*

A LETTER TO PROFESSOR DOOLEY CLEAR

Dear Dooley:

The important question of classroom treatment of replacement economy is raised by your discussion with your student Will B. Practical (Engineering Economy Pages October, 1938 and March, 1939). Perhaps Will's difficulty was that you merely expounded your "sunk cost gospel"—as Will calls it—when you discussed replacement economy near the end of your course. Expounding any sort of "gospel" at this time will hardly do the important job of getting students to reason clearly about such matters. What is necessary is to create a particular point of view at the very start of your course and to emphasize it throughout. This point of view is that economy studies are always comparisons of alternatives and that it is prospective *differences* between alternatives which are relevant in their comparison. It follows that all differences are necessarily in the future; whatever has happened up to now has already happened regardless of which of several future alternatives is selected.

Much of the fuzzy thinking about engineering economy so common in technical literature (sometimes even in the Engineering Economy Page) results from failure to recognize this simple principle. For instance, consider Will Practical's example of the machine "far out in a desert where cost of removal is great." He states that "such equipment has value because of its performance and to say that that value is negative for purposes of comparison the day after it is erected because its second-hand value is nil . . . just does not make sense. To say it is somebody's mistake if an unamortized loss occurs in such a case just is not fair."

Here Will has failed to realize that—like all economy studies—a replacement economy study is a comparison of future receipts and disbursements for given alternatives. In considering the economy of replacing this machine "the day after it is erected" the past investment in it is irrelevant because it is in the past and thus unaffected by the choice. On the other hand, the cost of removal is relevant because it is a future disbursement associated with one of the alternatives, *i.e.*, replacement; similarly the resale value, if any, is relevant because it is a future receipt associated with that alternative. The use of these estimated future disbursements and receipts (usually combined as net realizable value) in the economy study has no implication that this one-day-old machine is valueless to its owner, implies no censure of the engineer who chose it, and should not be thought of as "unfair" to anybody. It is only in case the economy study, comparing future receipts and disbursements for both alternatives, shows that an immediate replacement will pay that we may infer that the value of the machine to its owner for its present use is less than its net realizable value to him if he disposes of it. If this were true of a day-old machine we might indeed censure the engineer who selected it.

EUGENE L. GRANT,
Stanford University.

ENGLISH NOTES

DEVOTED TO THE INTERESTS OF TEACHERS
OF ENGLISH IN ENGINEERING SCHOOLS

J. L. VAUGHAN, *Editor,* University of Virginia

VI

ORGANIZATION AND CONDITIONS *†

By W. OTTO BIRK

Professor of English, University of Colorado

This study of the types of organization and conditions affecting the teaching of English to engineering students is based not only upon the hundreds of letters written to the Committee on English, but also upon the following surveys: the number of hours of *required* courses in composition, literature, and public speaking; the percentage of teachers in each rank teaching engineering students; and the type of organization by which English is taught.

Since experience and the consensus of opinion seem to indicate that the chief difficulties in all aspects of teaching English to engineering students are in universities with arts colleges, this type of engineering college was singled out for special study of organization and conditions—particularly those conditions involved in the kind of organization. In both independent technical schools and schools of mines, where all English is taught by one department and the instruction is planned for a homogeneous group of students, there should be no special problem in organizing the staff properly, in planning the kind of course that the college wants (though it might not be the most suitable), or in choosing prop-

* This is Chapter VI of the Report on Instruction in English in Engineering Colleges.

† Generous and valuable assistance has been given by the following teachers of English: Professor W. F. Scamman, University of Maine, who helped to plan the chapter; and Professor Alfred Westfall, Colorado State College of Agriculture and Mechanic Arts, Professor H. R. Young, Case School of Applied Science, and Professor Paul V. Thompson, College of Engineering, University of Colorado, who gathered the information about required courses.

erly qualified instructors. In colleges and universities that do not grant an A.B. degree, such as colleges of agriculture and mechanic arts (referred to hereafter as land-grant colleges), there is but little more of a problem. Here, too, only one department teaches all courses in English, and the students—though not all of them take only engineering or mining—are homogeneous for purposes of instruction, because all are primarily interested in science and presumably have the same vocational objectives. But in the engineering college that is grouped with an arts college in a university granting an A.B. degree (referred to hereafter as an A.B. university), there are all the troublesome problems of organization, type of course, and qualifications of instructor. Because of this condition and because colleges of engineering in this classification are more numerous than those in any other—there being nearly three times as many of them as of institutes and land-grant colleges combined—they were especially studied. To get most of the needed information, a questionnaire was sent to seventy-three deans of colleges of engineering within the classification. Of this number sixty-nine were returned. Since most of this questionnaire is not needed to understand the report, no part is reproduced here except the section that describes the kinds of organization, which is given later.

To avoid misunderstanding, it should be pointed out that the special studies were not made as ends in themselves, but as a means of providing a factual basis for the analysis and discussion of the subject of this part of the survey, namely, the organization by which English is taught and the conditions that may promote or hamper good teaching. For example, the concern here is not with the exact number of hours required in composition, literature, and public speaking by any one school, but with the typical or the general trend, because this might reveal a condition that stands in the way of good results in teaching.

To achieve the major objective of this chapter, answers have been sought to the following questions, the discussion of which constitutes the body of this section:

1. What kinds of organization are used for teaching English to engineering students?
2. How important is the kind of organization?
3. What factors limit results in teaching English?
4. What conditions stand in the way of getting and holding good teachers?

Kinds of Organization

In this study, the kind of organization is determined by the degree to which engineering students are segregated and the degree

to which their instructors teach only engineering students. With slight modification here and there, six kinds are used, as described in the questionnaire.* The kinds of organization, it should be noted, range from no segregation whatsoever to complete segregation of both students and instructors into a separate department within the college of engineering. Between these are important variations in the method of segregating, but they are so slight that they may be overlooked. This apparent similarity occurs in Nos. 3, 4, and 5, which should therefore be read carefully.

Based on segregation, the kind of organization is not of equal concern to all types of engineering schools. The independent technical institutes, of course, need not consider it; and the land-grant colleges seldom mention even a desire that a special kind of organization be provided for engineering students. The engineering colleges within A.B. universities, however, are so much concerned that they have devised all of the different arrangements described in the preceding paragraph. To these colleges the kind of organization seems important in teaching all aspects of English, but particularly the freshman course, which deals chiefly with usage and composition. The reason for this restriction probably is that nearly all schools (66 of the 69 that returned the questionnaire) require freshman English and that those requiring specialized

* These kinds are:

1. Department is wholly within the College of Engineering, independent of the general or Arts College department.

2. An autonomous staff, nominally a part of the general or Arts College staff, teaches engineering students only.

3. Sections especially provided for engineering students are taught by instructors from the general or the Arts College staff who are deliberately assigned to these sections and who teach engineering students only.

a. Instructors are members of the engineering faculty.

x. They plan their courses with the wishes of this faculty in mind.

y. They plan their courses according to the wishes of the general department.

b. Instructors are *not* members of the engineering faculty.

x. They plan their courses, however, with the wishes of the engineering faculty in mind.

y. They plan their courses according to the wishes of the general department.

4. Sections especially provided for engineering students are taught by instructors from the general or Arts College staff who are deliberately assigned to these sections, but teach other students also.

5. Sections especially provided for engineering students are taught by instructors from the general Arts College staff who are not assigned. (Sections are given to any instructor who is available.)

6. No method of segregating students is provided. (Engineering students take the course in English provided for other students in the University.)

writing courses in the upper classes can more easily find good instructors for them than for the freshman course.

The number of schools in this last group using each type of organization is as follows:

TABLE 1

No. 1.....	5	No. 4.....	13
No. 2.....	4	No. 5.....	5
No. 3.....	10	No. 6.....	29

The obvious conclusion derived from this table is that the prevalent type of organization is that in which engineering students are placed indiscriminately with all other students and are taught by members of the university department of English; but if all methods of segregating students are grouped, a large majority of schools (37 as opposed to 29) make some effort to segregate. Most of these thirty-seven, however, utilize instructors from the university departments, and not all of these instructors give their whole time to teaching engineering students; but nineteen have separate staffs teaching only engineering students.

An analysis of the questionnaire, together with a cross reference to the letters, shows that segregation of both staff and students is more complete than indicated by the table. Though only five colleges have their own independent departments, the four using No. 2 have the equivalent, because the instructors are only nominally members of the English staff in the arts college. Once assigned to the college of engineering, they are similar to a department in that college, with a chairman or head of staff, and they are responsible only to that college in planning courses and determining policy. These four, then, might be added to the five, making a total of nine colleges with their own departments. To this group might also be added two from No. 3, inasmuch as answers to questions 3*a* and *b* (see footnote, p. 410) state that members of these staffs belong to the engineering faculty and plan their courses according to the wishes of this faculty. They seem, therefore, to have enough autonomy to be classed under No. 2.

Further study of colleges using No. 4, moreover, shows that this classification might be misleading, because the large number suggests that many engineering schools do not want instructors to teach their students only; however, it often means merely that an instructor belonging to a specially chosen staff does not have enough engineering students to provide a full teaching schedule, and so he is given a section of other students. Since the colleges in this administrative predicament are trying earnestly to provide special staffs, they should also be added to those with segregated

staffs and students. Evidence indicates that there are at least three of these colleges, which make a total of twenty-two with special staffs to teach engineering students. Of all the A.B. universities reporting the type of organization, this number is one-third.

Importance of Kind of Organization

The value of one type of organization over another may be best determined by analyzing the information given on the questionnaire by deans in the A.B. universities. In answer to a query as to whether or not they are satisfied with their present type of organization most deans said that they are. Only eleven expressed any dissatisfaction, and most of these were not convinced that a change would insure better results in teaching. Only two were positive that a change was needed and that it would be beneficial. The kind of organization, however, that these eleven deans prefer, in place of the present kind—as given in the following table—suggests that the trend is still toward complete segregation:

TABLE 2

Present	Preferred	Present	Preferred
2*	1	6	1 or 2
2*	1	6	2
4	2	6	3
5	3	6	3
5	4	6	3 and 4 (combination)
		6	4

* These deans were not dissatisfied with results secured by No. 2, but thought that No. 1 would provide still better results.

Especially noteworthy, of course, is that each preference is for more segregation; that most of those preferring a change are now using No. 6; and that no one of these eleven wants No. 6. Moreover, this preference on the part of six colleges for some degree of segregation and of five for more segregation, when added to the thirty-two others that have segregation, suggests that a large number of colleges consider this kind of organization important.

Light from another angle on the importance of organization comes from fifty-nine answers to the following question: "Are your students taught English as well as you can reasonably expect them to be taught—as well, for example, as they are taught engineering subjects?" Only eleven deans said "No"—and these were not identically the same eleven, mentioned in the preceding paragraph, who preferred a different type of organization. This is less than a fifth of the total; yet the distribution, as shown in the following table may barely hint that the more complete the segregation, the less complaint about the results of the teaching:

TABLE 3

Plan No.	Number Satisfied	Number Dissatisfied	Per Cent Dissatisfied
1	5 all of colleges	0	0
2	4 using this plan	0	0
3	6	3	33
4	9	3	25
5	3	1	25
6	21	4	20

Against this record of thirty-seven colleges in A.B. universities that utilize segregation to some degree, there are twenty-nine that do not. These, of course, are using No. 6. Subtracting from this number the six favoring segregation still leaves twenty-three, or slightly more than a third of the sixty-six reporting the type of organization. Some of these colleges apparently continue with No. 6 because it is the conventional procedure in teaching English, which they accept through inertia; but many are positively opposed to segregation and have accepted or provided No. 6 deliberately.

Both presidents and deans of these schools have expressed themselves on this subject. In summary they oppose segregation chiefly because it is expensive to administer; because they do not believe in specialized courses in English for their students, especially in the freshman year—the so-called "engineering English"; because they think their students should not be deprived of the intellectual stimulation and broadening influence that might come from mingling with students of varied interests; and because they assume that the segregation of students in one college means segregation of those in every other college.

Exemplifying the foregoing point of view is the following statement by the president of an Eastern university, who says, ". . . it would be a mistake to give instruction in English from a narrow engineering standpoint, and to confine it to what is 'practical.' For the engineer needs a broad training and a sympathetic feeling for many fields other than his own." And a dean who has had years of experience as practicing engineer, teacher, and administrator, writes as follows from a large state college in the Northwest: "[This college] has never adopted the plan that English must be different for engineers and for others. . . . We believe it would be a mistake to require special courses throughout for engineers. These courses are one of their few contacts with courses outside their own special field, and we believe this broader outlook has as much value to them as anything that could be included in special courses."

Obviously, it is not the purpose of this report to advocate or defend any kind of organization or method; but some of the objections to segregation reveal a few common misconceptions that should be examined. These are that segregation necessarily implies vocational courses for engineering students, that the term "Engineering English" or "Department of Engineering English" must mean a peculiar kind of English, and that the logical result of segregating engineering students would be the segregation of students of every college or division of the university.

Since the purpose of segregation is to give engineering students a program to fit their needs, some colleges do make their courses strictly vocational by limiting them to instruction in writing letters, reports, and technical papers; but most colleges believe that engineering students—in common with nearly all other students, including a large majority of those in the arts colleges who are not majoring in English—need a special course only insofar as it aims, not so much at literary refinement, with emphasis upon description and narration, as at the writing of clear, orderly, and forceful exposition. These colleges see, moreover, that segregation helps so much to motivate the work that, instead of being a narrowing influence, it gives opportunity for making the course broader and richer than would otherwise be possible. Merely because the engineering students are in their own classes, they feel that the course is especially designed for them; and so a skilful teacher should be able to give them as broad, cultural, and literary a course as he chooses—even the kind they would resent in the mixed sections of an arts college.

Criticism of the term "Engineering English" derives also from an objection to vocational courses. Though some engineers and even a few teachers of English seem to like its professional flavor, the term is to most people an unfortunate misnomer, because it tends to bring all courses designed for engineers into bad repute as something specious. This result is unfair, because most colleges with segregated students attach no significance to the name. Officially, they call their courses "English for Engineers," but this term is soon shortened to "Engineering English," just as "Department of English in the College of Engineering" becomes "Department of Engineering English" or "Engineering English Department."

Furthermore, the common assumption that segregation of engineering students would logically require the grouping of students in every other college or division of the university is valid only if segregation is based narrowly upon the specific professional or vocational interests of the students. Since its purpose, however, is merely to provide an opportunity for the kind of course needed

by a majority of students, as explained previously, it need not lead to any such specialized brands as engineering, agricultural, or home economics English. A clear understanding of this point, and of the two preceding, is necessary if the merits of segregation are to be fairly assessed.

A study of all available evidence on the kinds of organization leads to no positive conclusion about the superiority of one type over another. It shows, of course, that a majority of the schools prefer a kind that segregates their students, and that a large number want one that segregates both students and faculty. Furthermore, it indicates a slight tendency toward segregation or toward more complete segregation, but none away from it. On the whole, however, it seems to show that most colleges are satisfied with whatever type of organization they now have. The deduction to be made from this situation, perhaps, is that the best type is the one that most nearly fits local conditions. If the general university department of English provides a suitable course and teachers who know how to handle young men and motivate their instruction, segregation ought not to be necessary; but where these conditions are impossible, a college may need some degree of segregation—perhaps, even, an independent department.

Factors That Limit Results in Teaching

The chief difficulty in the way of finding the factors that limit results is that there is no general agreement—among administrators, teachers of English, or practicing engineers—as to what constitutes satisfactory results *in teaching English to engineering students.* The letters collected by the Committee show clearly the divergent opinions, which need not be quoted here because they are given in Chapters II and III. Obviously, until most of those concerned have decided upon their objectives, they cannot know whether or not they have achieved them.

In addition, the president and the dean of the same college sometimes evaluate results differently. For example, the president of a state university in the Northwest, where English is taught by the arts staff, says positively, "The work in composition and speech at [this University] has been singularly effective. Although the courses are given in the college of letters and science, we have a young man teaching English to engineering and other technical students who has handled the work extremely competently. The engineering students enjoy his courses and feel that they get a good deal out of them." But the dean says in part, "Usually the work is not so effective as desired. The main failure seems to be that of motivation." Similarly, the president of one of the large

independent technical institutes writes confidently, "I believe the work in composition, literature, and speech at our own institution has been unusually effective." Yet the dean, with less confidence, says, "The work has probably not been so well done in the past as might be desired."

Because of their closeness to the problem, the deans might be expected to know more about it than the presidents, and so their dissatisfaction, freely expressed in their letters, should carry some weight; but when fifty-nine of them in A.B. universities, whence come most complaints, answered only "yes" or "no" to the question "Are your students taught English as well as you can reasonably expect them to be taught—as well, for example, as they are taught engineering subjects?", forty-eight said "yes." Probably this large number means that the question is too restricted, but it seems to be fair in expecting no more of teachers of English than of others. In the face of all complaints, however, this number might mean that the deans believe their students are "taught English as well as you can reasonably expect them to be taught" until basic conditions are changed.

What are these conditions? Those most frequently mentioned as standing in the way of satisfactory results are (1) that students are inadequately prepared for college work; (2) that engineering students are indifferent or antagonistic to instruction in English; (3) that instructors are not sympathetic with engineering students and so make little effort to understand their special problems; (4) that courses are not suitably adapted to the needs of engineering students; (5) that members of the engineering staff are indifferent or antagonistic to courses in English; and (6) that both teachers of English and engineering students carry too heavy a load. These several reasons will be discussed in order.

(1) Though many deans and teachers of English complain that most of their students come from high school inadequately prepared, this situation need not be discussed here inasmuch as it is dealt with adequately in Chapter II. Here, however, it must be referred to emphatically because any effort to evaluate the teaching of English must take it into account. Yet it should not be used as an excuse. Though it adds difficulty to the job, some means must be found to improve results in spite of it.

(2) A more common criticism is that engineering students are indifferent and often antagonistic to instruction in English; and this criticism is also more pertinent, because the college should be able to do something about it. A thoughtful statement of this situation is presented by a dean in an A.B. university,—a man with years of active interest in the teaching of English—who says, "It is my belief that, if the engineering students do not get as

much out of their English courses as they do from their engineering courses, it is not the fault of the English teachers, but is the engineering students' own fault. I do my best to impress my entering freshmen during Freshman Week with the importance of English, but 90 per cent of them come to the University with a fixed dislike of the subject. Few of them work hard enough to get much better than a passing grade and many fail. Those students who have some appreciation of the importance of English and really work diligently to master the subject are given fine training."

Strangely, of the many teachers of English (not heads of departments) writing on this topic, only a few mention any resistance on the part of the students, and these few seem to show a petulance that indicates an injudicial temperament, as in the following excerpt from an instructor in a land-grant college: "My experience is that teaching engineering students is a thankless task." In contrast to this is a typical comment from an instructor in the same type of college: "Having taught two years in an engineering school —after four years of teaching in a liberal arts college for comparison,—I find no great difference in the two types of students." Many others have written similarly favorable comments; but nearly all of them, it should be noted, are teaching in technical institutes or land-grant colleges. This fact may mean that students in these schools are better conditioned for English or that the teachers, because of temperament or training, have adjusted themselves to their special jobs. From all types of schools, however, there is enough complaint to justify an assumption that the students' attitude is in many colleges a serious factor in limiting good results. But what causes this attitude and how can it be remedied? Neither deans nor teachers answer these questions directly, though many of them imply, at least, that the answers may be found in the conditions discussed under topics 3 and 4.

(3) The complaint coming most frequently from deans is that the teacher of English does not have the proper attitude. Some say that his training is not appropriate, but since the whole subject of the teacher's preparation is discussed in Chapter V, it need not be taken up here. In criticizing his attitude, the deans charge that the instructor is not sympathetic with engineering students and does not or will not understand their problems, as shown by the following comments extracted from letters: "In my opinion, the most effective way to improve the teaching of English in engineering colleges is to employ thoroughly competent teachers who are interested in engineering students and who understand the engineering students' attitude towards English." "On the part of the English teacher, improvement could be made if he took pains

to acquaint himself with the work and ideals of the engineer and the engineering student." "More boys want to drop freshman English than almost any course in the University. I am afraid that the men with a Ph.D. in English are not very sympathetic with our engineering students. . . . Some of our men almost rebel against the work in English. I have had a number of students . . . say they would rather take it by correspondence because of the fact that they just do not like to be in the class with the two men that are teaching the work. . . ."

Despite these numerous criticisms, many teachers of English have recognized the problem, and some feel that they have solved it satisfactorily, as expressed in the following excerpts from their letters, which have particular value because they point out some conditions that prevent a better relationship between teacher and student: "For myself, and I think for many of my colleagues, it is not true that we take no interest in a student. The truth may easily be, however, that he thinks of himself as an embryo engineer, and we are thinking of him (at best) as a potential human being, or (at least) an unwilling writer and reader of English. I have frequently found, however, that a friendly personal understanding will make palatable to students an otherwise unpleasant course, and will make him an interesting individual to his instructor. But since he is oversupplied with classes and laboratories, and we are oversupplied with students and paper-work, we generally fail to establish within our one-semester limit, such a friendly relationship." Another says, "Classes of an ordinary complexion largely composed of engineering students often include several assertive, contemptuous, narrow-minded, second-rate people who are bumptiously proud of their incapacity and philistinism. These need to be dealt with confidently and teasingly in the hope that some of them will see the light beyond their noses. They should be made aware that there are many in the world who regard their attitudes as small, immature, and ill-informed."

Some significance, perhaps, should be attached to the source of these and similar comments from both deans and teachers of English. Nearly all of the deans who complain about the teacher's attitude are in A.B. universities, and most of them are in those schools that have no segregation. None are in the institutions that have complete segregation of students and teachers. Only a few deans in land-grant colleges make this complaint; and none of the deans or presidents in the independent technical institutes. Moreover, nearly all teachers (not heads of departments) who wrote on this topic teach in land-grant or technical colleges. The obvious interpretation, then, is that teachers especially chosen to instruct engineering students or engineering and other students of

similar interests are at least likely to handle their students with sympathetic understanding.

This conclusion, however, raises a serious question as to whether or not it is likely that many engineers overestimate the amount of motivation their students should have. Their many pleas for understanding and sympathy lead one to believe that they do. They almost cause one to accept the description of an obviously irritated instructor who wrote about his difficulties in teaching engineering students, "I always feel that I am trying to cram an unpalatable something into a squeamish stomach." They give the impression that here are a lot of exceedingly delicate or spoiled children who do not like to drink their milk; but since drinking something with meals is good form, they may have sugar water if only they keep still. These conjectures—unfair, of course—are made plausible because only rarely does any administrator say a word about standards. He does not complain that results are unsatisfactory because the English teacher expects too little or lets too many students slip through with a bare passing grade; nor do many of them say that engineering students, being as bright as others and preparing to fill positions in society equally important, should be expected to pass creditably any course that other students are required to pass. Only a few deans, for example, write on this topic as positively as the following: "All engineering students are required to take in freshman year the same English course which is offered to academic freshmen; and engineering students are scattered through the various class sections and are treated exactly as academic students are treated. Engineering students are also subject to the same requirement which applies to academic students, that no student may be admitted to the junior class until he is reasonably proficient in the writing of correct and idiomatic English prose."

(4) Another complaint, made as often as the preceding, is that courses are not suitably adapted to the needs of engineering students. Yet, as pointed out earlier in this section, there is no general agreement as to what the students need. One dean—in an independent technical institute—says, "We view the English courses as cultural rather than professional, it being the aim of our curriculum to enrich the lives of the students through contact with literature instead of merely giving them the necessary rudiments of composition." But another dean—in an A.B. university—says, ". . . most English instructors insist that the student should take his examples from classical literature rather than from technical work. This arouses antagonism, or at least fails to arouse interest in the students." Still another—in a large land-grant college—seems to consider the course in composition and speech

so vocational that he writes, "It may be found practical to have instruction given by engineers who have been successful and who realize its importance." Though there are exceptions, most deans who complain about courses share the opinions of the last two just quoted. They think that engineers should have what some call a "functional" course—one that includes largely, if not solely, instruction in composition and speech, which is limited to the specific needs of engineers. According to most opinions, these needs are the ability to write letters and reports and to speak on technical subjects.

Others are more moderate, especially in their opinions of the kind of composition course that ought to be taught. Their concern is not so much with content as with emphasis and with motivation. In regard to the former, they think that since much of an engineer's writing must be expository, the course should treat chiefly of exposition, though they would not confine it to the explanation of technical subjects. Moreover, they think that engineering students, with little likelihood of writing primarily for aesthetic appeal, should be instructed mainly, though not solely, in the means of gaining clarity, accuracy, and a modicum of grace. Beyond this desire for proper emphasis is merely a plea for motivation, which depends mainly upon the instructor, involving his attitude toward the students, his assignment of theme subjects interesting to his students, and his use of illustrations drawn from technical work.

(5) Though many contend that the results in teaching English can be improved by making the student more receptive to instruction through a change in the teacher's attitude and through the proper adaptation of courses, a still larger number think that even more can be done by the engineering faculty. Both presidents and deans in all types of institutions—but chiefly those in the A.B. universities and, next in order, those in the land-grant colleges and the technical institutes—say that the members of the technical staffs must give the teachers of English more support than they do; and some charge that many of these instructors are as indifferent and antagonistic to the teaching of English as the students. This same criticism comes from a few teachers of English also, but not from as many as from administrators.

Because a president's detachment may give him a view of the educational ideals and objectives of the faculty clearer than that of a dean, the following three comments have particular weight. These, which are similar to many others, are from presidents representing in order each of the three types of schools: A.B. university, land-grant college, and technical institute: ". . . I do not think that the English Department alone can do much more than

impart the fundamentals. It must have the coöperation of all other departments in the College. All must set up exacting standards and must insist that the students meet them. If a carelessly written report is accepted as satisfactory, the students begin to feel that what they have been told in their English class is, after all, not so important." "In my opinion comparatively little of the responsibility for ineffectiveness rests with the departments of English and speech. Many of these departments have made extraordinary efforts to waken in the minds of engineering students effective appreciation of the importance of English. These efforts commonly are thwarted because forces stronger than the departments of English and speech operate in opposition. . . . The more I learn of the subject the more firmly I am convinced that the departments of English and speech are . . . fighting an uphill battle against bad English; and that the most important factor for improving the situation, as it relates to engineering, is the example and the attitude of the engineering faculties and of those who manage the engineering industries." "I think the improvements . . . will come most effectively from outside of the English Department. I would welcome the day when every instructor in class would insist upon the use of correct English in both written and oral work. I think each instructor should, as a matter of practice, call attention to the defects exhibited by students, and this should be done in the most effective way, whether in class or in private conference after class."

Fewer deans than presidents comment on this phase of the problem, but those who do are no less outspoken, as shown by the following clear analysis of the situation: "The Engineering College, however, feels that it cannot place the entire responsibility upon the English department. If a student presents a problem in applied mechanics or in electrical engineering in which an error in mathematics occurs, the instructor feels obliged to reduce the grade and in many cases he demands that the problem be reworked correctly. On the other hand, in the case of English he frequently passes mistakes without comment. Therefore, when the instructors in the College of Engineering feel that it is incumbent upon them to correct reports and problems upon the basis of the correctness of the language used as well as on the basis of the mathematical accuracy and engineering factual information the problem of improved English will solve itself."

Inasmuch as no deans state that the engineering faculties cooperate sufficiently, one might suspect that they are modest, because many teachers of English do, as did one who said frankly and positively, "From the School of Engineering we have always received most hearty coöperation." A number, however, are as

critical as deans and presidents, as shown by the following remark from an instructor: "The complaint should not be that the instructor in English is not interested in the engineering student, but that the engineer is not conditioned to be interested in the English instructor." And the head of a department dismisses this whole survey as unnecessary with the conviction that "As a result of all the inquiries, you will, I venture to predict, come out with nothing that was not available in the findings of the admirable Wickenden report (c. 1925). We all knew then that engineers in industry were vociferous about the needs for training in English composition and speech." Then he goes on to say that we require no similar statements "to further weary us with this lip service. We need heads of engineering departments who are willing to give English and speech departments ample time for this work. . . ."

Because these unequivocal criticisms are made by only some of the administrators and teachers of English, though by a large number, an assumption may be that they come from institutions where conditions are not satisfactory. Certainly there are enough to suggest that the uncoöperative attitude of the engineering staff must account partly for the students' resistance, and must, consequently, stand in the way of effective teaching of English.

(6) Another barrier, mentioned less frequently, is the load carried by teachers of English and by students. Both administrators and teachers state that teachers have too many students and too many class hours, and consequently they are overburdened with the routine of meeting classes and grading papers. One dean, for example, gives this condition as the chief obstacle of effective teaching. "Our teaching," he says, "could be much improved if financial conditions were such that we could have more instructors and smaller sections. Many of our English Composition sections now have thirty and thirty-five students." A similar comment is made by an instructor, who points out also a serious consequence of overloading: "He [the teacher] realizes that any satisfying degree of success can come only when class instruction is supplemented with continued individual attention. The load of the average engineering English instructor makes this impossible. He can, perhaps, give occasional individual instruction to a few of his most needy students, but the few sparks he may strike only serve to deepen the general gloom."

Though other letters received from deans and teachers contain statements similar to the foregoing, they give no information that can be treated statistically. An attempt was made to get such evidence by means of the questionnaire, but, probably because of the phrasing of the questions, the answers were confusing, since a

number of deans gave only the average number of students in a section without giving the average number of sections for each instructor, and so the total average could not be computed. Moreover, some colleges without independent English staffs did not confine their report to those instructors teaching only engineering students. The figures, however, give some enlightenment. The hours range from 8 to 18, with 12 as typical; and the total average of students, where reported, ranges from 75 to 150. Of these latter, six colleges reported totals over 100, but probably others are also in this group, since only twelve colleges reported totals. No clear deduction can be made about these six either, though it is interesting to note that two of them, with 110 and 144, are among the five with independent departments, where the colleges of engineering are clearly responsible. Another college, with 110, utilizes plan No. 3 of segregation; two others utilize plan No. 4; and one, plan No. 6, or no segregation.

The total number of students for which an instructor is responsible is more important than the number of his class hours. This is especially true in teaching composition, which is an instructor's chief or sole duty in a college of engineering, because the bulk of the work consists in reading and evaluating themes. Since without this work, according to general belief, composition cannot be taught effectively, most arts colleges—and apparently colleges of engineering also—attempt to keep the total number of their students below a hundred. In general, the aim is to limit an instructor's load to twelve hours of classroom teaching (four sections, usually) and to about eighty students. This number, however, may be larger for instructors with some courses in literature, unless these also require numerous themes.

The student's load, mentioned occasionally as an obstacle to good results, refers to the amount of work in technical subjects. It does not mean here that the instructors in technical subjects include too many hours of their courses in the curriculum, but that they exact such a quantity of work that the student has no time left for any other subjects, whether they are officially in the curriculum or not. Since the student naturally considers his technical courses more valuable than others and must please these instructors, to whom he eventually will look for help in finding a job, he slights his English. This situation is expressed characteristically by the head of a department of English, who says in part, ". . . despite enthusiastic verbal endorsement by most of the influential members of the engineering staff, students continually find themselves under such heavy burdens of strictly technical work that they are indirectly encouraged to slight their work in English. Although this does not necessitate any lowering of our

standards in this Department, it does mean that a larger number of men do mediocre or grudging work, and thereby increase the difficulty of instruction in this subject."

Here is a condition so insidious that it probably is not mentioned by a larger number of critics only because they have not been conscious of it. Nor, perhaps, are the members of the technical staffs, though a teacher of English here and there believes that they crowd out English deliberately. Whether they are aware of it or not, everyone knows that they undoubtedly do apply pressure, just as do major professors in an arts college, who often take a disproportionate amount of their students' time, probably for the study of English; yet if colleges of engineering want to improve results in the teaching of English, they must curb this natural tendency.

Getting and Holding Good Teachers

The problem of getting and holding good teachers should logically be discussed as one of the factors that limit results, but it is important enough to be singled out for special emphasis. Inasmuch as both aspects of the problem come from similar conditions, the two can be discussed together. The first of these conditions is that many instructors think that teaching in an engineering college is a blind alley—and a rather gloomy one. The second is that no adequate means exists for bringing interested teacher and job together.

The principal complaints of instructors are that opportunities for advancement are slight; that the work itself is unattractive; and that those engaged in the work are likely to lose caste among other teachers of English. Though these charges are not made by all, and though they cannot be proved or denied, they come from so many teachers and may be so serious an impediment that they should be examined.

Are opportunities for advancement satisfactory? That is, can a competent instructor expect that in his own institution his promotion in rank and increase in salary will compare favorably with those of his colleagues; and if he is not satisfied in one college, can he reasonably expect to find a better position in the *same kind of work* elsewhere? Naturally these questions are relevant chiefly to those who are giving their whole time to engineering students or to engineering and others with professional and scientific interest—in technical institutes, in land-grant colleges, or in A.B. universities with completely segregated staffs.

The opportunities for teachers are always conjectural, based upon opinion. Presidents and deans seldom mention them, though

some say that the college must provide them, as does a dean in the following statement: "[There is a] general feeling among instructors of English that the teaching of composition to engineering students does not lead to advancement. I am sure in this connection that the administrative officials of engineering colleges must assume some responsibility. The teaching . . . must be made attractive to the right type of English instructor; that is, he must see a future in it." Another dean, however, whose college (in one of the largest state universities in the country) uses organization No. 3, praises the work of the English staff, but is ironically apathetic in doing anything to improve the status of its members. After explaining that English is taught by a separate staff with offices in an engineering building, but appointed by the University department, upon which it depends for rank and salary, he says, "This system has worked out satisfactorily. Professor [X] has a very satisfactory staff under him. There is, however, one serious criticism of the system that I would have, namely, that these men are not treated like full-fledged members of the English Department of the Arts College as to academic status. . . . Professor [X], the highest ranking man in the group, is an assistant professor; so you can see that none of them has advanced academically on a comparable basis with the Arts College staff. This situation may be corrected to some extent through the years, but undoubtedly these men will continue to operate under some handicap, which seems to me rather unfortunate. It is a matter that I have not yet had occasion to take up with the Arts College. . . ." And yet this dean, Professor X, and several of his instructors have been in this college at least a minimum of eight years! Incidentally, this situation reveals the weakness of plan No. 3, which leaves the members of the English staff dangling between the university English department and the college of Engineering, with no one actively concerned about their welfare.

Heads of departments of English, if they mention this topic at all, are generally vague, especially those in arts colleges who are responsible for segregated staffs or instructors assigned to teach engineering students. The frankest statements come from heads in the institutes or in colleges with independent departments. A characteristic statement is from a head of department in a large institute, who says, "There is some opportunity for promotion and advancement in salary for the man who devotes himself to teaching English to technical students. But less, I think most of us will agree, than for the man of science, or for teachers of English in arts colleges." This point of view is borne out by the head of an independent department in an A.B. university, who writes frankly of his own experience: "Up to this time there has been

some but not enough advancement to attract the better men who propose to teach English. I know that when I decided to teach in an engineering school rather than in a college, some of my beloved teachers were astonished and warned me not to throw away my time teaching technical students. The teachers sincerely believed that there was more future elsewhere." Probably they were right, because this man, warmly praised by his dean, has been teaching in the same college about ten years and is still an assistant professor at $2800. And no one is directly responsible for his status except the dean of the college of engineering! Apropos of this situation is the complaint of a dean that one barrier to good results is "the employment of immature English instructors, especially in composition." But if deans do not provide for their own staff any better than for this man and for Professor X, how can they hope to get and hold mature teachers?

Since opportunities open to young instructors may be revealed by the present situation, a study was made of the number of teachers, ranks, and salaries in the group of colleges about which least is definitely known, those in the A.B. universities. In all of the 66 schools reporting on this topic there are 692 teachers of English, distributed according to rank and plan of organization as shown in the following table. Under each rank is given in the first column the number and in the second column the percentage.

TABLE 4

Plan	Professors	Assoc. Profs.	Ass't. Profs.	Instructors	Assistants
No. 1	3— 9%	8*—25%	6—19%	9—28%	6—19%
No. 2	1— 4	2— 7	1— 4	9—33	14†—52
No. 3	4—10	2— 5	9—22	23—56	3— 7
No. 4	7—11	5— 8	18—30	29—48	2— 3
No. 5	10—26	4—10	8—21	17—43	——
No. 6	39— 8	39— 8	80—16	189—38	145—30
Total number and total average %	64— 9%	60— 9%	122—18%	276—40%	170—24%

* Six of these are in one college.
† Thirteen of these are in one college.

As an indication of opportunities based on existing jobs, the foregoing table is probably not accurate, because those colleges using plan No. 6 undoubtedly reported all members of the English staffs who would be likely to teach engineering students instead of only those actually teaching them. Obviously, they could scarcely do otherwise, inasmuch as engineers are not segregated. A similar

reservation may be necessary in considering the returns from colleges using plans No. 4 and 5, because, even though they segregate students, they do not always assign to them the same teachers.

Probably a fairer idea of possible opportunities could be gained from a tabulation of teachers in each rank within colleges that segregate both students and teachers, that is, colleges using plans No. 1, 2, and 3. These colleges report exactly one hundred teachers. To preserve anonymity, the colleges are designated by numbers and they are not arranged in any special order.

TABLE 5

	Professors	Assoc. Profs.	Ass't. Profs.	Instructors	Assistants
1	0	0	1	1	0
2	1	6	2	6	5
3	0	1	0	0	0
4	1	0	2	1	0
5	1	1	1	1	1
6	0	0	1	0	0
7	0	1	1	0	0
8	1	0	0	1	0
9	0	0	1	3	0
10	2	0	3	6	0
11	0	0	1	6	0
12	0	1	1	1	0
13	0	0	1	2	0
14	1	0	0	1	3
15	0	0	0	3	0
16	0	1	0	4	13
17	1	0	1	2	0
18	0	1	0	1	0
19	0	0	0	2	1
	8—8%	12—12%	16—16%	41—41%	23—23%

Conspicuously revealed by this table is that few teachers with only engineering students in an A.B. university need aspire to a full professorship. The opportunity is not even so great as shown here, because in each of two institutions the professor is merely in general charge, giving most of his time to the arts college. The total number of associate professors is here misleading because of the large number in one college. This means not merely that most of the teaching is done by assistant professors and instructors—chiefly instructors—but that the direction of the work also is given to those in the lower ranks. In seven of these schools there is no one above the rank of assistant professor; in two others there is no one above the rank of instructor; and in two others there is no

one between a single professor and the instructors. More important is the fact that in two of the five independent departments, where the deans of engineering are responsible, the head is not a professor. In one he is an associate professor, and in the other an assistant professor. Equally worthy of notice, however, is that there are not so many assistants as might be expected in A.B universities with graduate students to care for, provided the thirteen in one college are omitted.

Inasmuch as all of these colleges segregate both students and teachers, there is some fairness in comparing the totals and the average percentages with the totals and average percentages in the land-grant colleges; in the independent technical institutes, both of which teach the same kind of students; and in ten representative arts colleges. For this last group, the percentages may not be entirely accurate, because they are based upon figures taken from catalogs, which do not always list assistants.

TABLE 6

	Professors	Assoc. Profs.	Ass't. Profs.	Instructors	Assistants
A.B. universities No. 1, 2, and 3	8— 8%	12—12%	16—16%	41—41%	23—23%
Land-grant colleges	28—15%	30—16%	48—26%	70—38%	8— 5%
Institutes	12—15%	17—21%	22—27%	29—36%	1— 1%
Ten arts colleges	68—24%	36—13%	51—18%	100—35%	30—10%

Not much information could be secured about salaries because many schools, for one reason or another, did not give it. Some idea can be gained, however, from the following tabulation of average salaries for each rank paid in the schools listed in Table 5.

If these salaries are representative, then the whole scale is low. Only a few stand out as adequate, though others might also be considered very good in some localities. It is possible, of course, that all salaries are unusually low because of the depression, but this explanation does not seem valid for a large group. Even if it were, there are so few teachers in the upper ranks that not many young men can look forward to the higher salaries. It is true, of course, that in some of these universities the teachers may be assigned to the college of engineering only temporarily and go back to the arts college, where they are promoted; but this doubtful probability does not help those who want to make a career of teaching engineering students, nor does it provide for these students mature teachers.

Although teachers of English are concerned about rank and salary, they complain more frequently that the work is not attrac-

TABLE 7

	Professors	Assoc. Profs.	Ass't. Profs.	Instructors	Assistants
1	——	——	$2800	$ 600 (part time)	——
2	$5000	$2980	$2700	$1960	$1300
3	——	$3200	——	——	——
4	$3700	——	$2200	$1600	——
5	$4990	$2400	$2100	$1400	$1000
6	——	——	$2100	——	——
7	(Not reported)				
8	(Not reported)				
9	——	——	$2150	$1800	——
10	$3700	——	$2333	$1700	——
11	——	——	$3300	$1900	——
12	——	$2200	$1800	$1500	——
13	——	——	$3000	$2000	——
14	$5000	$4000	$3200	$2100	——
15	——	——	——	$2000	——
16	——	$3000	——	$1902	$ 685
17	$2850	——	$1985	$1500	——
18	——	$2850	——	$2100	——
19	——	——	——	$1200	——

tive. What they mean is that in nearly all colleges the courses are elementary; that most of these are in composition, with their heavy burden of paper work; that they can never have the stimulus that comes from teaching majors or graduate students; that the position is not accorded the dignity of importance by members of either the arts college or the engineering college; and that they have little time for the study, research, and publication that bring professional growth and advancement. Those in the land-grant colleges and the independent institutes have the added complaint that they miss the association with colleagues who are teaching advanced courses and that, even when they have time for study and research, the college libraries do not contain the books they need. Those in the institutes, however, seldom comment on the narrowness of their program, probably because it includes a high percentage of literature.

The following comments, by teachers representing both land-grant colleges and A.B. universities, are typical: "The average English instructor coming out of our graduate schools automatically steers away from specialized teaching in the engineering college. His training has not been in that direction; his tastes do not lead him that way, and his normal desires for advancement lie within the field of his specialty. . . . A man who has spent years of preparation to teach courses in American literature does not feel that there is much future for him if he must give the time to

teaching specialized courses for engineers." ". . . the English instructor's world exists quite outside his college [college of engineering]; sometimes he feels that he is a foreigner, even at times unwelcome. In his college, English signifies chiefly grammar and rhetoric and endless themes—most of them requiring no creative criticism, only a consumption of time. Too frequently his class teaching requires but a low degree of showmanship. It is true that the young instructor, wherever he go, must expect to perform these duties. But too often, for the teacher of engineers, they continue to be the staple work on into the higher ranks." "Because of the scarcity of advanced work and the rarity of well-prepared students who wish to know much about literature and to read much and widely, naturally the professor of English in a technical college is never going to use anything like his full capacities or knowledge. The long apprenticeship in most colleges makes the same thing true for some instructors for many years, and in some instances for life; but here we leave all hope of that sort behind. Besides, we are a 'service department,' in which only the head will receive a salary comparing with salaries paid to technical men of the same academic rank."

Since much of the dissatisfaction is with the type of course, which gives an instructor little opportunity to teach literature, a study was made of the number of hours in composition, in literature, and in speech *required* by colleges in A.B. universities, land-grant colleges, and technical institutes. No attempt was made to discover the number of hours elected, because accurate information is not available; moreover, there is much evidence that in schools where electives are offered, very few students take them. The following table gives the average of *semester* hours required in each type of institution:

TABLE 8

Freshman Year	Composition	Literature	Speech	Total of English
A.B. universities	5½	⅙	⅙	5¾
Land-grant colleges	4⅓	½	¼	5¼
Technical institutes	4⅛	1	⅓	5½
Upperclass Years				
A.B. universities	1¾	1	⅕	3½
Land-grant colleges	3	1	1⅓	5
Technical institutes	2⅛	2¾	1⅜	6½

Total of English for All Years

A.B. universities	9½
Land-grant colleges	10+
Technical institutes	12

The totals are interesting; but the instructor's complaint that teaching engineering students is unattractive is illuminated much more by the average hours of literature required in the engineering colleges, particularly as compared with those required in composition. Contrary to what the layman might expect, the independent institutes, serving only technical students, *require* more than twice as much literature as the other types of schools, a condition that might explain why teachers in these schools seem to be better satisfied than others. On the other hand, colleges in A.B. universities, the reputed abiding place of culture, *require* the least. This record is even worse when one considers that colleges using plans No. 1, 2, and 3, with both students and teachers segregated in independent departments or their equivalent, require next to no literature in the entire four-year curriculum, as shown in the following table:

TABLE 9

No. 1—(5 independent departments)	1 hr. (Average in all years.)
No. 2—(4 autonomous staffs)	0 hr. (Average in all years.)
No. 3—(10 segregated staffs and students)	⅕ hr.*(Average in all years.)

* Two hours at one college were not included because they were required by only a small minority of departments.

It must be remembered, of course, that electives are open to engineers in many of these schools. According to the meagre evidence, the number of students taking them is closely in proportion to the number of required hours, the largest number being in the institutes and the smallest in the A.B. universities. Apparently, however, this number is not large enough to change the record much.

Since most of the required courses in literature are elementary, the only conclusion that can be drawn from these figures is that any one who wants to give his professional life to teaching engineering students will have only a slight chance to do any work beyond the elementary, with a preponderance of it in composition. If this kind of work, then, does not attract first-class teachers of English, the colleges of engineering cannot expect to get them or hold them unless they are willing to enrich their curricula with more courses in literature.

This condition, more than any other, is responsible for a third common complaint of the teachers: that they lose caste with their colleagues in the arts colleges. Because they must teach elementary courses—elementary even among undergraduate courses—they are often looked upon as inferior. So, too, are those teaching composition in the arts colleges; but generally they are, at least, in the general department of English and may sometimes have a

chance to teach advanced courses. This chance the teachers of engineering students do not have. Moreover, they cannot get it by changing to the arts college, because, even if they are recognized as capable, they are usually thought to be rusty in the advanced courses and out of touch with the problems of the arts college department.

That this situation is true is believed by a man who has until recently given years to teaching engineering students in an A.B. university. He writes, "If the school is entirely a technical one, a successful instructor may undoubtedly look forward to slow but steady promotion. If he is successful as a writer or in the affairs of national learned societies, he may even look for calls from other institutions in the same field; but, as a very good friend of mine told me recently, to enter the profession of teaching English to technical students solely is equivalent to 'committing professional suicide,' so far as receiving calls from the better American institutions where English and American literature departments are stressed is concerned. One always has to consider the fact that an English department in a technical institution is always a service department and may never hope to encourage students to major in literature or writing. For this reason, I personally chose not to accept a position in such an institution, believing that it would lead into a blind alley." A similar opinion is held by the head of the English department in a large technical institute, where his record of service is long and well-known. In answer to an inquiry about the opportunities of a teacher of engineering students, he says, "If this means his opportunities in a school of technology, they are probably as good as those of the teacher of technology. That is, he will be advanced in rank and salary as far as the conditions in the department permit. If the question refers to his opportunities in a non-technical college, they are practically nil. 'Leave hope behind all ye who enter here' should be the motto over the door of the school of technology entered by an instructor in English. He will never be called to another kind of institution unless he has perchance made friends who have a 'pull' or has made a name for himself outside, quite apart from his work as teacher in his school of technology; unless, for instance, he has won distinction as a writer."

If this plight of the teacher is accurately described—if he is seldom able to transfer from the engineering college to the arts college, then an important, fundamental question is, "Do the colleges of engineering provide sufficient opportunities within themselves for professional advancement and personal satisfaction?" Based upon the evidence, the answer is decidedly "no."

Yet, in spite of these handicaps, there are competent persons

making a career of teaching engineering students—probably because they are in exceptional colleges with the broader opportunities—and some of these, now in lower ranks, might be available for better positions in other colleges, probably to take charge of the work. If these qualified teachers could move to other technical schools, their chances for advancement might be increased. In addition to these experienced teachers, there must be some promising young men willing to undertake this work. At present, however, there is no adequate means of bringing together the teacher and the job.

In the first place, many deans of engineering do not appoint their teachers of English, and often they have no voice in the selection. Obviously, this situation exists chiefly in the A.B. universities, but somewhat in the land-grant colleges. Information gathered on this topic by means of the questionnaire shows that 22 deans out of 43 are not consulted about appointments. What happens, then, is that they get instructors who are chosen to teach in the arts college and who promptly become dissatisfied.

But more serious, inasmuch as many deans in all types of colleges do participate in making appointments, is the fact that those administrators who want to select qualified teachers have only chance knowledge of available candidates from among either the experienced or the untried. It seems reasonable that better choices would be made if there were some central exchange which would have available the records of all instructors who are either teaching engineering students or want to. This might be set up by the Committee on English of the S. P. E. E., though, in order to keep it above suspicion, it should be directly in charge of a committee or a director with no desire for another position. Not only would this exchange improve instruction and give teachers an enlarged opportunity, but it would also help to prevent the present shameful waste of talent now on hand and available.

Conclusions

The more important conclusions to be drawn from this phase of the survey are as follows:

1. The plan of organization is not in itself essential to satisfactory results, which can be secured under any kind if the teachers are competent and other conditions are propitious. Most administrators in A.B. universities, however, prefer that their students be segregated, and many think that the teachers should be definitely chosen to teach only engineering students. The general tendency in these schools is toward segregation.

2. A special effort should be made in every institution to instill in the students a favorable attitude toward English.

3. The attitude of students can be shaped properly by sympathetic and understanding teachers, by courses adapted to the interest and needs of engineering students, and by the precept and example of the technical staff.

4. The teaching load of the instructor in English should be reduced, where necessary, to a maximum of 12 hours of class work and 80 students, especially for those teaching only composition.

5. The technical staff should allow their students time to do good work in the English courses on their schedule.

6. The ranks and salaries of teachers of English should be commensurate with those of the technical staff. In the A.B. universities this need is especially conspicuous. In many departments there should be more teachers in the higher ranks, particularly those at the head of the staff.

7. In addition to rank and salary, the teacher's work should be made more attractive by according it recognition as an integral and indispensable part of an engineering curriculum, and by providing in the English program more courses in literature than are now found in most curricula.

8. Some means should be devised for bringing together teacher and job. In the first place, deans in technical schools, especially in A.B. universities, should have more voice than they do in choosing the English staff; and in the second place, some kind of agency should be established to provide administrators with the records of both experienced and prospective teachers.

MECHANICAL ENGINEERING PAGE

Those who personally dominate are heroes for the hour; those who build men are immortals.

R. L. SWEIGERT, Georgia School of Technology, *Editor*

COMMENTS BY M. M. BORING OF THE GENERAL ELECTRIC COMPANY ON THE SUBJECT "DO INSTRUCTIONAL METHODS USED IN MANUFACTURING PROCESSING LABORATORIES CONTRIBUTE TO TRADE TRAINING OR TO ENGINEERING EDUCATION?"

My background is definitely prejudiced to our own particular situation. I think we would be perfectly content to have no shop work whatever. I don't think it is of any particular value chiefly because our boys are in direct contact with the manufacturing situation, and we are able to show them the widespread new materials. We have definite classrooms and factory courses with new and modern equipment. So I think I am prejudiced on that basis. I do, however, realize that there must be a certain amount of real value in shops, which may vary somewhat. If a boy has had it all through high school, I do not see any particular value in it for him in college. *We have been doing much in the last year or two with the theory of cutting of metals. If we can teach a boy what happens mathematically when we are cutting metal, I think there is a great deal more that comes from that than he gets from shop. I can see very little value in making certain definite projects.* I would say that if our machine tools were used to demonstrate materials, and not some of the things that were known a long time ago, if we used our shops on such a basis, using tools to demonstrate more or less of the theory, they would be valuable. We can say that the shops can be made to demonstrate rather than to be producing men with a very small amount of trade skill.

COMMENTS BY C. H. CASBERG, UNIVERSITY OF ILLINOIS

I think that we sometimes make these boys take these courses because we find that they don't know much about the cutting tools and things like that. Maybe we do abuse these boys once in a while.

I am going to try to outline briefly what we have done at the University of Illinois. In 1914 shop laboratories at the University of Illinois began a changeover from what we commonly called manual training type of instruction to what is called a production type of instruction in shop laboratories. And gradually we have changed this until we have what Professor Sweigert calls the manufacturing processes type. Some of the major changes that have taken place are these: In 1925 the forge laboratory was abandoned and a course in heat treatment was installed in its place. In 1928, pattern making by the students was discontinued, and we substituted for that, pattern de-

signing. I might explain that very briefly, when a pattern was designed, a blueprint was handed to the pattern maker and the pattern maker did his own designing. I think it is now changed in some industries. They really have some pattern designers, because great savings can be made in the foundry in the production of castings if the patterns are properly designed. The student starts with very simple patterns, giving blueprints and the pattern equipment that is necessary. Students use sketches in showing their design. Some students who are not very good in making sketches prefer to make line drawings. The work is similar to that of the machine designer. Most of our shop laboratory courses occupied two four-hour periods a week, and that was cut in 1929 to two three-hour periods a week, and in the last two years we have cut the time to two classroom periods and one three-hour laboratory period, which is a cut from eight hours to five hours. I believe that the student is getting as much out of five hours a week as he did formerly in eight hours.

THE T-SQUARE PAGE

DEVOTED TO THE INTERESTS OF THE
DIVISION OF ENGINEERING DRAWING

A. W. LEIGHTON, *Editor*, Tufts College

OUR RAW MATERIAL

When a machine or other engineering structure is designed and built, fully as much care goes into the examination and selection of the raw material as into the actual fabrication. Based upon an exact knowledge of characteristics and properties, the raw materials are treated to meet the requirements of the structure.

The selection of freshmen, the raw material of the engineering college, is done largely upon a basis of demonstrated ability in mathematics, physics, English, etc., with little or no emphasis upon previous training in the graphic language. The exclusion of mechanical drawing as a prerequisite to acceptance in freshman engineering classes has been thoroughly debated with still no evidence of crystallized opinion one way or the other. The result is that college departments of mathematics, chemistry, physics, English, etc., may anticipate with reasonable accuracy the quality of their raw material. Not so, however, with the department of drawing. Their material is as variable as the proverbial New England weather. Unless there is segregation upon a basis of ability in mechanical drawing, it becomes necessary to devise a freshman course which will suit this variety of preparation. Much more effective and perhaps more advanced work might be accomplished with our freshmen if they could be admitted with a prescribed knowledge of the elements of our science.

In order that we might have a better picture of the secondary school training our freshmen receive, we asked them to tell us about it in a questionnaire last September. A summary of this experience sheet as answered by over 400 entering students may be of interest to members of the division and is hereby offered.

The tally represents a close approximation. All percentage data in items 2, 3, and 4 refer to the 52% who had secondary school drawing.

1. 48% had received no training in mechanical drawing.
2. Course plan
   - *a.* Years of study: ½—8.4%; 1—40.5%; 1½—3.6%; 2—21.5%; 2½—.8%; 3—14.4%; 4—9.6%; 5—2%.
   - *b.* Periods per week—3.
   - *c.* Length of periods—50 minutes.
3. Course content (stressed)

   Lettering, 86%; linework, 38%; geometric construction, 66%; two and three view drawing (orthographic), 80%; sketching, 44%; auxiliary views, 38%; intersections, 43%; development, 32%; iso-

metric, 37%; oblique, 33%; perspective, 40%; revolution, 28%; sections, 31%; screw threads, 46%; detail drawings, 26%; assembly drawing, 24%; architectural drawing, 19%; gearing, 17%; cams, 16%; charts, 14%; nomographs, 2%; inking or tracing, 60%; textbook, 31% (others followed blueprints or class lecture material); lettering books or form sheets used by about 50%.

4. Course method
   - *a.* Copied from blueprints or other supplied drawings—74%.
   - *b.* Allowed to pursue work most interested in—30%.
   - *c.* Men instructors—87%; women—13%.
   - *d.* Did instructors teach other subjects—yes—35%.
   - *e.* Girls and boys taught separately—71%; together—29%.
   - *f.* Most courses introduced with lettering—use of instruments simple constructions and block drawings.
   - *g.* Understood explanations—85%.
   - *h.* Hardest to understand
     1. Revolutions
     2. Perspective
     3. Intersections
   - *i.* Elected course—66%; required—34%.
   - *j.* Found course interesting—66%; average—30%; dull—4%.
   - *k.* Lesson procedure—some lecture work; much individual instruction; much copy work; many worked as fast as subject coculd be assimilated thus depriving class of unity; "each man on his own;" "few exams;" "year's work posted, work as will."
   - *l.* General comments were many, interesting, and variable. A very few follow: "poor equipment;" "part of geometry course;" "classes noisy;" "too hurried;" "part of Trig. course;" "course helpful;" "not enough sketching;" "periods too short;" "only one year available;" "mixed with art course."

It is interesting to note that many took drawing only in junior high school so that of the whole entering class only about 30% received training which would be useful in college work.

The University of Illinois has prepared a syllabus for high school teachers and the New England Drawing Teachers Association has made similar recommendations to its members, but so far as the writer knows, this is as far as coordination has been attempted. It would seem that more might be done to encourage the teaching of drawing in the secondary field.

ELIOT F. TOZER,
Chairman of the Department of Drawing,
Northeastern University

The National Drawing Competition Committee for 1939–1940 is as follows:

JOHN H. BUTLER, New Mexico State College
J. LAWRENCE HILL, JR., University of Rochester
FRIDJOFT PAULSEN, San Mateo Junior College
CHARLES E. ROWE, University of Texas
ELIOT F. TOZER, Northeastern University
STANLEY G. HALL, University of Illinois, Chairman

The General Regulations for this Competition will be published in the January issue of the T-Square Page.

NEW MEMBERS

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BACON, RINALDO A., Instructor in Mechanical Engineering, University of Texas, Austin, Texas. H. E. Degler, V. L. Doughtie.

BENSON, LEONARD R., Instructor in Mechanical Engineering, University of Texas, Austin, Texas. Byron Short, M. L. Begeman.

BOOHER, EDWARD E., College Representative, McGraw-Hill Book Co., 330 W. 42nd St., New York City. F. L. Bishop, Nell McKenry.

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TURNER, WILLIAM W., Assistant Professor of Architecture, University of Notre Dame, Notre Dame, Ind. W. L. Shilts, F. W. Horan.

WALTON, SYLVAN B., Assistant Professor of Mechanical Engineering, University of Kentucky, Lexington, Ky. W. E. Freeman, C. C. Jett.

WILCOX, CARL C., Head, Dept. of Mechanical Engineering, University of Notre Dame, Notre Dame, Ind. R. J. Schubmehl, W. L. Shilts.

133 new members 11/8/39

COLLEGE NOTES

Duke University.—Pursuant to a resolution of authorization adopted by the last meeting of the Board of Trustees, the Division of Engineering of Duke University was reorganized and is now operating for the first time as the College of Engineering of Duke University. W. H. Hall, Professor of Civil Engineering, who formerly was Chairman of the Division of Engineering has been named Dean of Engineering.

The College of Engineering is the third undergraduate college of the University, the other two being Trinity College for Men and the Coördinate College for Women, and is the result of a plan of expansion and reorganization that has been going on for a number of years. It occupies its own independent quadrangle on the East Campus. Three courses in engineering, Civil, Electrical, and Mechanical, are offered, with the laboratories of the three departments housed in separate buildings.

The College opened this fall with a total enrollment of 216. This is close to the maximum possible which has been set at 225. Beginning with this year, the full time teaching staff has been increased to four men in civil engineering, four in electrical engineering, and five in mechanical engineering.

L. R. Ranson, Instructor in Electrical Engineering, resigned to become Director of Research and Development of the Clark Controller Company, Cleveland, and his place is being filled by Mr. C. R. Vail, of the General Electric Company.

The fifty-third year of instruction at the **Michigan College of Mining and Technology** is marked by a record enrollment of 875 students, an increase of 14 per cent over the peak reached last year. During the past decade the number of men and women taking work at Michigan Tech has increased 118 per cent.

A factor contributing to the expansion of the college during the past year has been the erection of a men's residence hall. The building, the first of its sort on the campus, accommodates 204 students, three-fourths of whom are freshmen. Completely fireproof, the dormitory is built in Tudor-Gothic style, and is constructed of red brick with stone trim and metal casement windows. A special feature of the structure is a sheet-copper roof. An infirmary, a laundry, and a student-valet room are a part of the dormitory.

Three new instructors were appointed to the faculty this fall. They are L. E. Davis, instructor in ore dressing, who has degrees from Michigan Tech and the University of Washington; E. J. Swifka, instructor in mechanical engineering, who holds a B.S. degree from the University of Wisconsin and has had several years' experience in industry; B. F. Schubert, director of music, who has been supervisor of music and director of bands in a number of large schools in Illinois.

The following promotions have been approved:

L. A. Rose, from associate professor of English to professor and head of the department of languages; D. P. Sherman, from assistant professor to associate professor of economics; T. E. Richards, from assistant professor to associate professor of mechanical engineering; F. J. Tolonen, from assistant professor to associate research professor of metallurgy; G. R. Elwell, from instructor to assistant professor of mechanical engineering; R. B. Miller, from instructor to assistant professor of forestry; Jacob Jacobson, from laboratory assistant to instructor in shop practice; Eugene Sullivan, from laboratory assistant to instructor in metallurgy.

The forming of a new department, that of history, was also approved by the board of control. Dr. Ella L. Wood, formerly head of the language department, is in charge.

The curriculum in forestry production has been lengthened to include four years, in place of the previous three. A degree of science in forestry is awarded upon completion of the course of studies.

University of Notre Dame.—Walter L. Shilts, who has been Acting Dean for the past year, will continue to serve as Assistant Dean, and as Head of the Department of Civil Engineering.

Edward J. Maurus has been retired from active duty after 47 years of teaching, and his place in the Civil Engineering Department is being filled by James A. McCarthy. Mr. McCarthy received his undergraduate and graduate training at the Massachusetts Institute of Technology and for the past several years has been associated with the United Fruit Company as structural engineer. Previous to that he spent several years with the firm of Fay, Spafford and Thorndike, Consulting Engineers.

Last year Carl C. Wilcox, formerly power engineer of the Studebaker Corporation, and more recently a consulting engineer, was added to the staff during the illness of William Benitz. He now succeeds Professor Benitz, who has retired, as Head of the Mechanical Engineering Department. Professor Wilcox is a graduate of Ohio State University and at an earlier date was instructor at Michigan State College. This staff is likewise augmented by the

addition of C. Robert Egry, formerly of the University of Detroit and before that, Purdue University. He received his training at Purdue University.

John A. Northcott, Jr., who has been identified with the Electrical Engineering Department since 1922 has been made Head of that Department. He succeeds Jose A. Caparo who is forced by ill health to restrict his work to a light teaching schedule.

Alexander R. Troiano, a new teacher in the Department of Metallurgy, is replacing Carl Floe who has returned to Massachusetts Institute of Technology. Dr. Troiano received his A.M. degree from Harvard in 1931, M.S. in 1937, and Science Doctor in 1939. He taught at Middlesex College 1931–1936, and at Harvard 1937–39.

In the architecture department, Frank Montana replaces Gerald Brubaker who has resigned to enter active practice. Mr. Montana received his training at New York University, from which he received the Bachelor of Architecture degree in 1933. He received the Paris Prize Scholarship in 1936, and in 1939 received the Graduate Diploma from École Nationale des Beaux Arts.

The following are changes in staff in the Faculty of Applied Science, **Queen's University,** Kingston, Ontario, for Session 1939–1940.

Civil Engineering: Alexander Macphail, C.M.G., D.S.O., LL.D., B.Sc., Head of the Department of Civil Engineering, retired. W. P. Wilgar, D.S.O., B.Sc., takes Professor Macphail's place as Head of the Department of Civil Engineering. C. V. Armour, B.A.Sc., has been added to the staff.

Norwich University opened the 1939–40 academic year with the largest student body in its long history, a step in the direction of eventual expansion to an enrollment of five hundred. John M. Thomas, who, for the past year has been Chairman of the Administrative Committee administering the affairs of the University during the absence of President Porter Adams, was elected to the office of President by the Trustees this past summer; when Colonel Adams' resignation was accepted, due to his continued ill health.

In keeping with the larger enrollment, several members have been added to the engineering faculty; and of further benefit to those graduating from Norwich, a Placement Bureau has been created. The new members are Robert W. Hydeman, M.A., who will assist in the department of Mathematics and Civil Engineering; James W. Ingalls, C.E., who will be Associate Director of the Bureau of Industrial Research; and Frank G. Smith, B.S., to be Laboratory Assistant in the Engineering Departments and Bureau of Industrial Research. Merton E. Ashton, N.U., '24, has been ap-

pointed Alumni Secretary, and he will also conduct a Placement Bureau for the benefit of Norwich men.

Robert W. Hydeman, who has been added as a member of the Civil Engineering faculty, graduated from Miami University, Ohio, in 1935, received his M.A. in Mathematics from Syracuse in 1937, and completed two years of graduate work in Mathematics at Massachusetts Institute of Technology this past year. During his graduate work he acted as a part-time instructor at Syracuse and M. I. T., and he has also served in a teaching capacity at the Extension School and Summer Schools conducted at Syracuse.

Mr. Smith, who is to be the Laboratory Assistant in Electrical Engineering, was graduated from Norwich with a B.S. in Electrical Engineering in 1931. Since graduation he has been engaged in machine work and private enterprise.

Mr. Ashton graduated from Norwich in 1924. He has since been connected with the Barnard School, and later served with the Personnel Department of Crown Can Company. The Placement Bureau which he has now organized will be available for the benefit of graduates and present cadets.

The Bureau of Industrial Research, created last Spring, has got under way with anticipated early benefits to smaller Vermont industries. This Bureau has been given valuable advancement by the appointment of James W. Ingalls, the new Associate Director of Industrial Research, as Assistant to Douglas Howes, Professor in Electrical Engineering and head of the Bureau. Mr. Ingalls graduated from Thayer School of Civil Engineering in 1911, and did graduate work at the University of Michigan. Since that time he has had several years of engineering experience in the fields of business and industry. He has also been connected with college teaching and administration for thirteen years, being formerly the Head of the Department of Industrial Engineering at Northeastern University in Boston, Mass.

To provide housing facilities for the continued growth of Norwich, work has been started on the foundation of a new barracks, which will care for 138 men. This building will be ready for occupancy next fall. It is being erected on the east side of the parade, and its architecture will harmonize with Cabot Hall, the barracks completed a year ago.